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Lucretius...on discovering truth

"...no fact is so simple that it is not harder to believe than to doubt at the first presentation. Equally, there is nothing so mighty or so marvellous that the wonder it evokes does not tend to diminish in time. Take first the pure and undimmed lustre of the sky and all that it enshrines: the stars that roam across its surface, the moon and the surpassing splendor of the sunlight. If all these sights were now displayed to mortal view for the first time by a swift unforeseen revelation, what miracle could be recounted greater than this? What would men before the revelation have been l[illegible]ve as possible? Nothing, surely. So m[illegible]ve been that sight—a sight which no one now, [illegible] admit, thinks worthy of an upward glance into t[illegible]inous regions of the sky. So has satiety blunted the appetite of our eyes. Desist, therefore, from thrusting out reasoning from your mind because of its disconcerting novelty. Weigh it, rather, with discerning judgment. Then, if it seems to you true, give in. If it is false, gird yourself to oppose it."

—Lucretius, 1st Century B.C.

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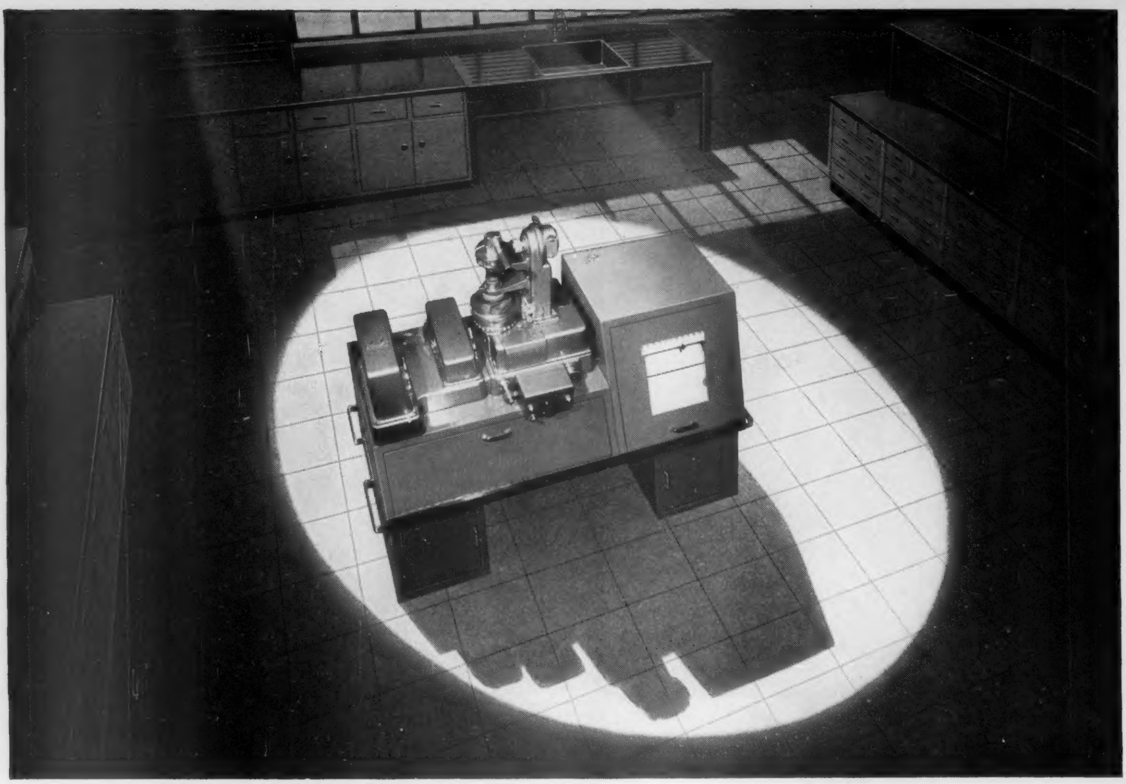

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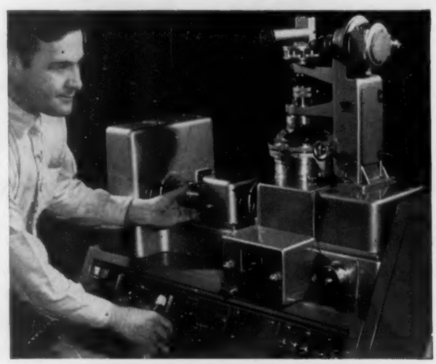

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*Willard	10.00–12.50	13.00–17.00	14.00–18.00	25.00–35.00
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SCIENCE

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Seeing Is Believing and Vice Versa

Does the conduct of a scientific experiment, once science has advanced beyond the descriptive or natural history stage, require of the investigator anything more than a refined version of the qualities expected of a good witness in court? That is to say, does the conduct of a scientific experiment involve anything more than the careful and detailed observation of a certain set of phenomena by the use of certain instruments? We suppose that the answer is no if the scientist testifies only about those events that he sees directly with his own two eyes. But then you do not have science, only the description of some pieces of equipment. When the report turns to the *results* of an experiment, then something more is involved. Since there is sometimes the temptation to regard an experiment simply as the precise observation of a certain set of phenomena, it may be worth while to remind ourselves of what is also required.

This distinction between ordinary testimony and the report of the results of a scientific experiment was emphasized by Pierre Duhem (1861–1916), a French physicist who is known today primarily for his contributions to the history and philosophy of science. After making this distinction, Duhem went on to examine the meaning of doing an experiment. To understand his conclusions it is not necessary to refer to the very latest developments in experimental inquiry. It will be sufficient for us to consider, as does Duhem, the relationship between what a novice might see upon first entering a physics laboratory stocked with ordinary pieces of equipment and what a physicist might report about his own activities there.

Suppose that our novice upon entering the laboratory spies a tangent galvanometer. He might say that he sees insulated copper wire wrapped around a circular frame in the center of which is suspended a small steel bar. He might also comment that the direction of the bar is indicated by a pointer that can be read against a scale. But our physicist in reporting his own activities probably would make no reference to the small bar or to the direction in which it is pointing. He would say that he is measuring the intensity of the electric current flowing in the copper wire. To bridge the gap, however, between his own report and the testimony of the novice, the physicist might add that he is bringing the reading of the pointer on the scale into a certain formula. But if the physicist continues his efforts at explanation he will find himself giving a course in electromagnetic theory, for the formula is a consequence of the fundamental laws of that discipline and its full understanding requires that one first understand those laws.

All of which means that there is a lot of homework to be done before one becomes a scientist. But to do an experiment requires something more than mere study. There is the simple circumstance that not every event that the novice observes has the set of phenomena under investigation as its cause. To distinguish those events arising from the set of phenomena under investigation from those created or mutilated by the workings of the instrument requires the use of the theory that the novice has just learned. But in addition to learning the theory, the novice must also accept it as true. For if he regards the theory as false he will have no basis on which to distinguish between appearance and reality, and if he regards a rival theory as true he will make the distinction in a different way. In addition to the precise observation of a set of phenomena, the conduct of an experiment also requires the interpretation of those phenomena. If seeing is believing, then so also is believing seeing.—J.T.

5 September 1958, Volume 128, Number 3323 SCIENCE

CURRENT PROBLEMS IN RESEARCH

Solar Spectroscopy

A new vacuum spectrograph at McMath-Hulbert Observatory makes possible greater accuracy in solar spectroscopy.

Orren Mohler

It is extremely difficult to find a laboratory source of radiation that is as intense and reliable as the sun. Perhaps this is the reason why the sun has for many years provided the radiant energy for experiments that have been decisive in the development of essential instruments and techniques of modern spectroscopy. At the present state of the art, the compliment is being returned. Measurement and analysis of spectrum photographs are the principal means of studying the sun, and various spectroscopic procedures provide the observations which are the bases for deductions of solar chemical composition and physical conditions of motion, temperature, pressure, density, and electric and magnetic field strengths. Historically, progress in the determination of these elements of solar structure has depended heavily upon the development and perfection of observing apparatus. There follow some examples of the parallel growth of the instruments and of concepts in solar spectroscopy and the description of a new vacuum spectroscope for use in solar studies at the McMath-Hulbert Observatory of the University of Michigan. A brief discussion of some of the unexpected results obtained with this instrument makes clear a need for future improvements in solar astronomical instrumentation.

Genesis of Solar Spectroscopy

Solar spectroscopy began with Isaac Newton's (*1*) summary statement that "the sun's light is a heterogeneous mixture of rays" and that these can be "parted or sorted from one another." Newton drew this conclusion from the results of personal repetitions of experiments, common in his day, with triangular glass prisms and beams of light of narrow cross section.

Newton described one of his first experiments in this way: "In the sun's light let into my darkened chamber through a small round hole in my window shut, I placed a lens. . . . Immediately after the lens I placed a prism, . . . and thereby the round image which the lens alone did cast upon the paper might be drawn out into a long one with parallel sides. . . . Instead of the circular hole . . . 'tis better to substitute an oblong hole shaped like a long parallelogram with its length parallel to the prism. . . . The edges of the prism and lens must be covered with black paper glued on. . . . All light of the sun's beam let into the chamber which is useless and unprofitable to the experiment ought to be intercepted with black paper. . . . It's difficult to get glass prisms fit for this purpose, and therefor I used sometimes prismatic vessels made with pieces of broken looking-glasses, and filled with rainwater. . . ."

Newton's observations with this primitive spectroscope led him to conclude: "Whiteness and all grey colors between white and black, may be compounded of colors, and the whiteness of the sun's light is compounded of all the primary colors mix'd in due proportion."

From the time of the discovery of the colors in the white light of the sun, each improvement in the spectroscope has revealed new features in solar radiation, but progress was rather slow in the years following the publication of Newton's *Opticks* (1704). Almost a century elapsed before the discovery of dark lines intersecting the continuous band of solar spectrum colors was announced by Wollaston (1802) (*2*), in a paper that is considered by many to be the ultimate model of occult description. Wollaston saw only a few of the strongest dark lines interrupting the continuous spectrum, and he seemed to regard them as boundaries separating the seven homogeneal colors urged by Newton as the elemental components of white light.

There is a completely adequate reason for the leisurely rate of advance in spectroscopy and optical science in the 18th century, and the quotation given above from Newton's *Opticks* shows that he was well aware of the cause of the trouble. Although the lenses and prisms in the spectroscopes of Newton and Wollaston were as large as many now in use, the poor quality of the glass prevented the formation of very good optical images. Such technical imperfections often led experimenters to amusingly incorrect generalizations.

This situation was completely changed during the first quarter of the succeeding century. The Swiss glassmaker Guinand (*3*) discovered a method of producing first-quality glass, and reproducible spectroscopic measurements become possible. Under Guinand's tutelage Joseph Fraunhofer mastered the art of making optical glass and, in attempting to perfect his methods of manufacturing scientific instruments, made a detailed study of spectra of flames, of the sun, of the planets, and of a few of the brighter stars. Incidentally he produced both transmission and reflection diffraction gratings, the first measurements of the wavelengths (which can be considered precision designations of color) of solar spectrum lines, a map of the position of 600 dark lines in the sun's spectrum, and the first convincing demonstration that the dark lines in the spectra of astronomical objects were characteristic of the observed object and were not prod-

The author is on the staff of the McMath-Hulbert Observatory of the University of Michigan, Pontiac.

ucts of the instruments or methods of observation. Furthermore, Fraunhofer noted an apparent coincidence in wavelength between the dark lines, which he had labelled "D," in the spectrum of the sun and the close pair of yellow lines visible in the spectrum of a candle flame.

Growth of Spectroscopic Concepts

More than thirty additional years of improved observation and measurement, made possible by Fraunhofer's refinements in the art of glassmaking and the construction of scientific optical instruments, were to pass before the recognition of a principle that connected emission and absorption of radiation in light sources. Then, in 1859, just a hundred years ago, G. Kirchoff (*4*) announced the fundamental principle that has made spectroscopic chemical analysis of the sun's atmosphere possible. This relation is: The ratio between the emissive power and the absorptive power is a constant for all bodies at a given temperature. At the time of its announcement, Kirchoff's law completely reoriented research in physics, and its implications for the understanding of the radiation of the stars are still being studied in detail. Kirchoff demonstrated experimentally one of the most important consequences of this statement—namely, a gas which emits a line spectrum also absorbs the lines it emits. He further concluded from direct comparison of emission lines in laboratory sources with the absorption lines in the solar spectrum that at least 21 of the terrestrial chemical elements must also be present on the sun.

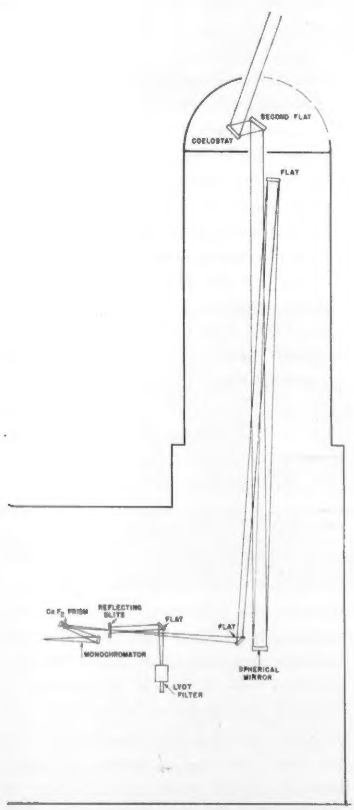

Fig. 1. Diagram of the McGregor solar tower telescope of the McMath-Hulbert Observatory. See Fig. 2 for a diagram of the spectroscope used with this telescope.

But one more fundamental principle was needed to provide a broad base for solar spectroscopic studies. At about the time that Kirchoff and his colleague, Bunsen, were reporting their methods of spectroscopic chemical analysis, a rather puzzling suggestion concerning the spectrum colors was being debated in the scientific journals. Doppler (*5*) suggested that the observed color of a luminous body depended on its state of motion with respect to an observer. Fizeau (*6*) correctly, and independently of Doppler's suggestion, directed attention to a small change in wavelength in the absorption lines in the spectrum that would result if the sun were in motion, which would destroy the nice coincidence predicted by Kirchoff between laboratory emission lines and solar absorption lines. Lockyer verified Fizeau's ideas, in the case of the sun, when he recorded variable distortions, shifts, and broadenings of solar spectrum lines. He recognized these as evidence of motion in the solar gases. "The accompanying changes of refrangibility of the lines in question show that the absorbing material moves upwards and downwards as regards the radiating material and that these motions may be determined with considerable accuracy" (*7*).

After the discovery and verification of Kirchoff's law, and of the Doppler-Fizeau method for the measurement of motion in the line of sight, it soon became apparent that all of the results of laboratory spectroscopy could be applied directly to the study of the chemical and physical constitution of the sun, and solar spectroscopy was well begun.

In the years that followed, a number of instruments were designed especially for the analysis of solar radiation, and experience in their use demonstrated that definitive, quantitative answers to solar spectroscopic problems could be obtained only by the use of highly perfected designs and procedures. Today the best that spectroscopy can give to solar astronomy is not yet quite good enough. The McGregor tower telescope and the vacuum spectroscope of the McMath-Hulbert Observatory (*8*) are representative of attempts to meet these needs. This recently (1955) completed installation embodies a number of improvements that have brought new accuracy and facility to the study of solar structure. Figure 1 is a diagram of the telescope, and Fig. 2 is a diagram of the spectroscope.

Some Features of the McMath-Hulbert Spectroscope

There are four features in the construction of the McMath-Hulbert spectroscope that should be given detailed mention because they may indicate directions toward possible solution of the more persistent problems in solar spectroscopy.

Firstly, wherever possible, mirrors have been used in place of lenses so that the achromatism of the entire system may be as perfect as possible. Perfect achromatism assures correct focusing of invisible radiation, and it is required if all wavelength regions between the cut-off at 0.00029 millimeter by asmospheric ozone and the cut-off at 0.0240 millimeter by water vapor are to be studied without making extensive adjustments for each change of wavelength.

Secondly, the entire spectroscope is sealed inside a vacuum tank, thus eliminating all possibility of image deterioration as a result of air currents flowing around and across the optical parts. A secondary but still very important advantage, that insures uniform and reproducible results, is obtained because the vacuum tank protects the mirrors and gratings from dust and condensation. These considerations are different from those that lead to the construction of large laboratory vacuum spectroscopes. Air is removed from laboratory instruments to obviate absorption of ultraviolet and infrared radiation. In solar spectroscopy the amount of air traversed by a beam of radiation in a spectroscope is trivial in comparison with the long path it must travel through air in order to reach the instrument from the sun.

Thirdly, the dispersing element of the spectroscope is one of the best of the new, modern gratings. It is a plane grating, ruled in an aluminum coating supported by an optically figured, flat Pyrex

base. Modern methods of ruling gratings produce very high concentration of the dispersed light in desired spectral regions. Such gratings have been made possible by many years of careful development of techniques and instruments by many gifted scientists, and they represent a remarkable improvement over the prototypes first ruled directly in glass by Fraunhofer. The latest steps toward the perfection of gratings are being taken by Babcock, at Mount Wilson Observatory; Harrison, at Massachusetts Institute of Technology; Richardson, at Bausch and Lomb; Strong, at Johns Hopkins University; and Gerasimov, at the Leningrad Institute for Technical Optics. Babcock ruled the grating of the vacuum spectroscope of the McMath-Hulbert Observatory especially for this instrument in 1954. The Babcock grating is mounted on an electrically driven turntable which can be rotated to permit either photographic or photoelectric registration of any desired spectral region. During the course of photoelectric recording, the grating may be rotated continuously at rates between 1.0 and 0.005 degree per hour to provide a slow drift of the spectrum across the photoelectric exit slit (Fig. 2).

Fourthly, a small prism spectroscope (see "monochromator," Fig. 2) is placed in the beam of radiation before the entrance slit of the main instrument (actually the spectrum produced by this component of the vacuum spectroscope is about one-fortieth as long as the spectrum used by Newton). The prism spectroscope acts as a filter, or monochromator, with adjustable transmission characteristics. With its assistance, most of the incident solar radiation can be excluded from the main instrument and only the portion under investigation admitted. This is a rather erudite way of following Newton's important, and often neglected advice, quoted above: "All light of the sun's beam let into the chamber which is useless and unprofitable to the experiment ought to be intercepted with black paper." Throughout the spectroscope absorbing screens and diaphragms eliminate all possible stray radiation.

Performance of the Instrument

Each of the features of the construction of the McMath-Hulbert vacuum spectroscope listed above contributes in part to the high-contrast, high-resolution performance of the instrument. A spectral image has perfect contrast if test absorption lines, known to be absolutely black, are imaged with no radiation filling in their dark centers. The ratio of the intensity of the background of continuous radiation upon which the black test line is superposed to the intensity of the radiation at the bottom of the line image therefore approaches infinity as a limit, as the image approaches perfection. Since some energy is scattered from all real optical surfaces, perfect contrast can never be achieved, and a contrast ratio greater than 25 is very good indeed. Different measurements of the contrast ratio of the present instrument have been made by several different observers, using different standard lines, and the resulting values of the ratio lie between 25 and 60. The higher values can be obtained only with the most exacting attention to the adjustment of the prism monochromator, so that it admits an extremely small amount of radiation into the larger instrument.

Undoubtedly, much of the credit for this performance should be attributed to the excellence of the Babcock grating, as also should the high resolving power of the instrument. The practical resolving power of a spectroscope is defined as the ratio of the mean wavelength of two lines, just clearly visible separately, to their difference in wavelength. The value of this characteristic of the vacuum spectroscope of the McMath-Hulbert Observatory varies, with the conditions of use of the grating, from 100,000 to more than 1 million and for general observations lies in the range 400,000 to 800,000.

Lines in the Solar Spectrum

If the absorption lines in the solar spectrum had been first observed with spectroscopes as powerful as this, it is doubtful that they would have been called lines. It is evident from a glance at Fig. 3 that in a high-contrast, high-resolution spectroscope, the solar lines look like stacks of bristles, or short streaks.

Figure 3 is a reproduction of the appearance of the first line of the Balmer series of hydrogen, Hα. The smooth, very narrow lines are produced by the water vapor in the earth's atmosphere. The largest variations in the edges of Hα, when the spectrum comes from a quiet part of the sun, occur on the redward side of the line (the right side, in Fig. 3). If these structures are interpreted, following Lockyer, with the aid of Doppler and Fizeau's principle, then they are evidence of the motion of small clouds of gas on the sun, but differences of temperature and density from volume to volume must also play a large part in

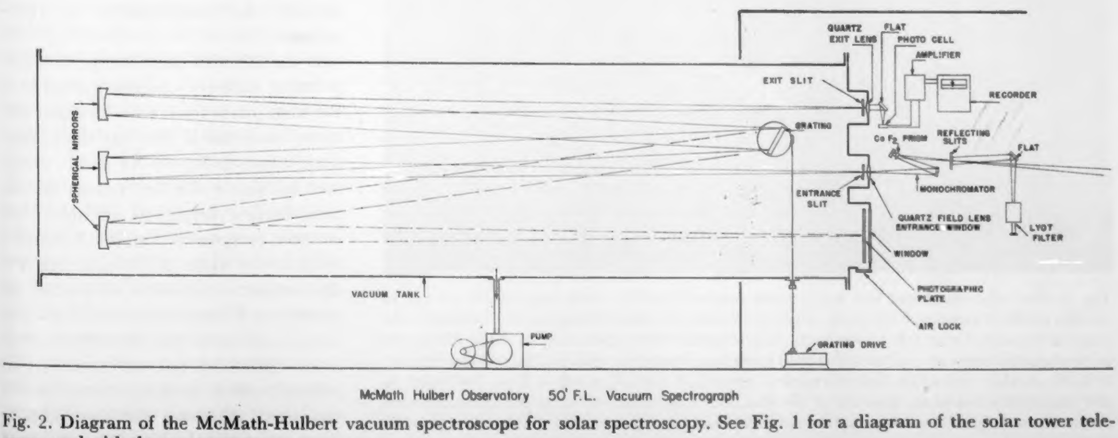

Fig. 2. Diagram of the McMath-Hulbert vacuum spectroscope for solar spectroscopy. See Fig. 1 for a diagram of the solar tower telescope used with the spectroscope.

causing the streaks. Oddly, the observation of the spectrum of an active (but not too active) part of the sun, containing transient features such as sunspots, reveals lines much less "bristly" than the lines from the more quiescent areas. The active regions referred to are called plages, and although they are the part of the sun in which spots and flares and other, often explosive, phenomena burst forth, the relatively smooth lines they produce are evidence that some force, possibly magnetic, restrains the normal motions of the small gas clouds.

The average thickness of the streaks, a measure of some average dimension of the clouds, is about 3500 kilometers on the surface of the sun. At the earth's distance, 3500 kilometers, or slightly more than half of the earth's radius, subtends an angle of about 5 seconds of arc. Bristles on the edges of the "lines" in the solar spectrum are produced both by changes in the total length of the streaks and by shifts of these elemental component structures. There seems to be no evidence at Hα for an underlying uniform dark central core on which the streaks are superposed. The width of the individual streaks, interpreted as motions, has a minimum value of 30 kilometers per second and an upper limit of about 50 kilometers per second. Measurements of the centers of the individual streaks range within plus or minus 16 kilometers per second, with the average shift from the mean position averaging only 0.6 kilometer per second.

The changes in intensity that make the streaks visible can also be measured. Values of the ratio of the difference of intensity from the average value along the spectrum line to the mean value range from 15 to 30 percent. At the edges of the line, these values may go as high as 80 percent. The wider bristles are generally more intense at their centers than the narrow ones. A careful examination of the lines in Figs. 3 to 6 provides strong evidence that the streak-like bristles originate in an outer layer of the sun, the chromosphere. Near the edge of the sun the bristles widen and finally merge without perceptible interruption into the bulge on the edge of the spectrum which is produced in the chromosphere.

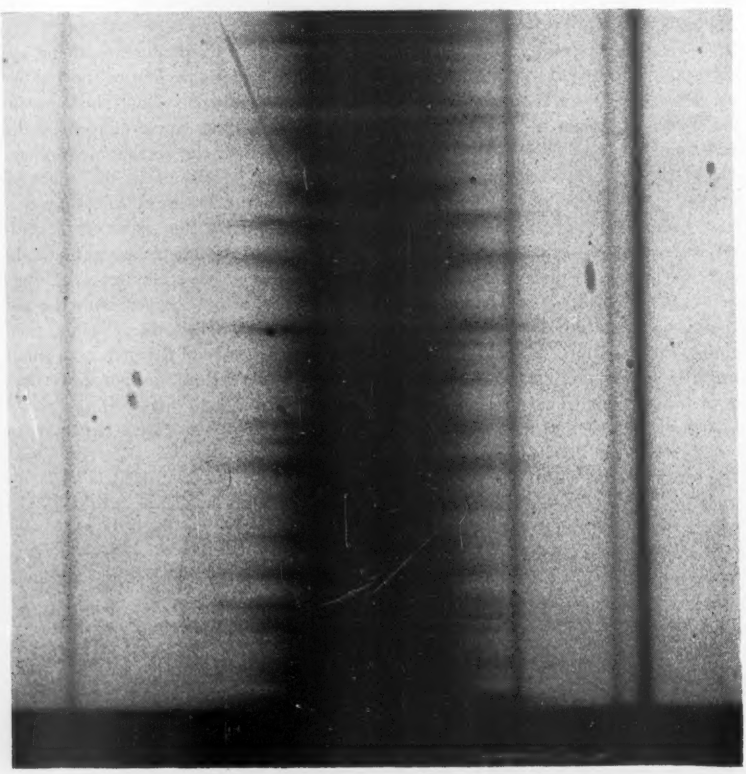

Fig. 3. The solar spectrum line Hα (center vertical band), which appears as a stack of bristles or short streaks. The upper edge of the dark horizontal band at the bottom is the edge of the sun. From left to right, the wavelengths (in angstroms), and identifications of the spectral lines are: 6561.105 (HOH, earth); 6562 (?); 6562 (Hα, sun); 6563.533 (HOH, earth); 6564.075 (HOH, earth); 6564.220 (HOH, earth). Note the bulge at the edge of the sun at the position of the Hα line. This is produced by the chromosphere. A distance of 1 millimeter along the spectral lines is equivalent to ? seconds of arc on the sun.

Figure 4 shows the second member of the Balmer series of hydrogen Hβ. The Hβ streaks are nearly identical in kind with those of Hα, but there is some evidence of an underlying, uniform, live center. They continue without interruption into the chromospheric bulge at the edge of the sun and, just as in the case of Hα, are doubtless formed chiefly in the outer atmosphere of the sun. Close by Hβ appear a strong line of iron and weaker lines of ionized and neutral chromium, iron, and vanadium. The streaks in the lines of the metals are generally similar to those in the hydrogen lines, from which one concludes that either all of these details of line structure are formed in the same layers of the sun or, if they are formed at different levels, the characteristics of the different regions are closely correlated.

Near the center of the line of ionized calcium, labelled "K" by Fraunhofer (Fig. 5), the streaked structure, which except for somewhat greater coarseness, resembles hydrogen in size and distribution, reaches its most conspicuous development in the entire solar spectrum. The center of the K line is flanked by two bright borders that have been for many years past the subjects of intensive study and the sources of many concepts of the circulation of the sun's upper atmosphere. Nearly always the violet component of the emission (left center in Fig. 5) is the brighter, and this difference in brightness persists to the edge of the sun. It is possible to suppose that the observed asymmetry results from the expansion of hot masses of gas rising through the chromosphere to cooler regions.

If the slit of a spectroscope is illuminated by ordinary sunlight, instead of by the solar image from a well-focused telescope, then the K line has the appearance shown in Fig. 6. All of the streaks and bristles in the line vanish, but the predominant brightness of the violet emission component remains. A measurement of the width of the outer edges of the emission components shows that this quantity is directly related to the sun's intrinsic brightness, just as similarly measured widths of K lines in other stars are related to their brightness (9). The observational discovery that the widths of the central emission structures in the K

line are connected with stellar brightness provides one of the strongest indications of the fundamental importance of the study of the detailed structure within the solar spectrum lines. Special spectroscopic instruments are required for the recording of this elusive structure with high precision.

Desirable Instrumental Improvements

Observations at the McMath-Hulbert Observatory have shown clearly that the streaks and bristles of the spectral lines revealed by the vacuum solar spectroscope at Lake Angelus give physical data for some of the small structures on the sun. The next great need is an instrument that will make possible spectroscopic observation of the very smallest solar features, structures that in some cases subtend angles no larger than ½ second of arc.

The general lines of construction for the desired improved spectroscope would doubtless be similar to those already tried in the vacuum spectroscope of the McMath-Hulbert Observatory, but with even greater attention paid to the elimination of all parasitic light by the use of more powerful auxiliary monochromators, improvement of all optical surfaces, both reflecting and refracting, and especially the improvement of diffraction gratings. Much of the success of a very large solar spectroscope depends on the production of more perfect and larger diffraction gratings than now exist; to produce them seems to be well within the capabilities of known techniques for ruling gratings.

Specifications for a High-Resolution Observatory

The smallest feature visible in a solar image is determined in large part by the earth's atmosphere. At all observatories, experience shows that the most favorable conditions occur in the early morning hours and at high altitudes. The telescopic image is most tranquil and most clearly defined under these conditions. The image is also much brighter at high altitudes than at sea level. Such considerations indicate that a solar observatory seeking the best possible definition of the image should be located high above sea level and should have an unobstructed eastern horizon.

It may be that in some future time it will be possible to make telescopic solar observations from above the earth's atmosphere, and indeed some important

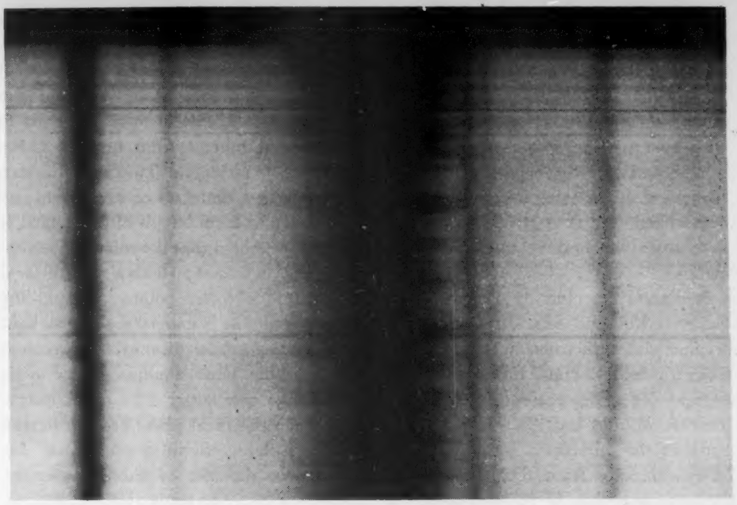

Fig. 4. The solar spectrum line Hβ (center vertical band). The lower edge of the dark horizontal band at the top is the edge of the sun. From left to right, the wavelengths (in angstroms) and identifications of the spectral lines are: 4859.747 (Fe, sun); 4860.220 (Cr^{II}, sun); 4860.992 (Fe^{I}, sun); (?) (Hβ, sun); 4861.849 (Cr^{I}, sun); 4861.953 (?); 4862.551 (Fe^{I}, sun) and 4862.604 (V^{I}, sun). Note that the bristles in the lines of metals correlate with those in the Hβ line. Scale along the lines: 2 millimeters is equivalent to 1 second of arc.

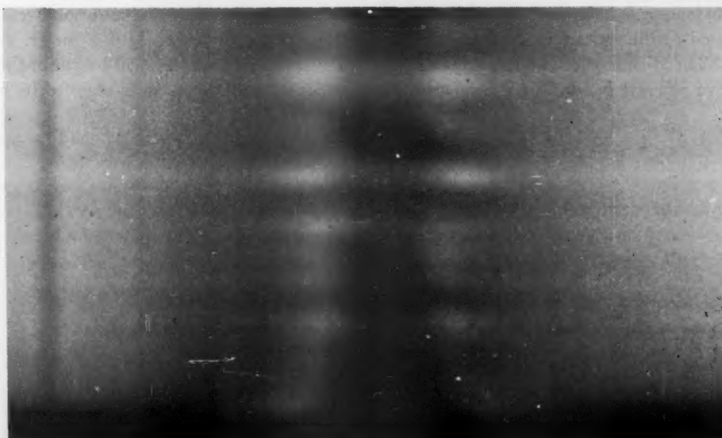

Fig. 5. (Top). The solar spectrum line K, Ca^{II} (center vertical band). The upper edge of the dark horizontal band at the bottom is the edge of the sun. From left to right, the wavelengths (in angstroms) and identifications of the spectral lines are: 3932.638 (Fe^{I}); 3932.916 (Fe^{I}); 3933.532 (K2V) bright line; 3933.683 (K3) dark line; 3933.863 (K2R) bright line. All lines are sun lines. Note the similarity between the line structures in Figs. 3, 4 and 5. Scale along the lines: 2 millimeters is equivalent to 1 second of arc. Fig. 6 (Bottom). The solar spectrum line K made with integrated sunlight. For identification of the lines, see Fig. 5. The bristles are absent; the solar light on the spectroscope slit is not focused into a sharp image.

exploratory observations have already been made. However, the equipment required for precision, quantitative, solar records must be very large and must be guided on the sun for minutes of time with no error larger than a few tenths of a second of arc. The size of the telescope and its associated equipment are determined by geometrical considerations from which there seems to be no escape.

Radiation detectors at present in use for recording the sun, such as photographic plates, thermocouples, and photoelectric cells, demand that the smallest angular size to be recorded must have a linear scale of at least 25 microns (1/40 mm) in the telescope's focal plane. It follows directly from the geometry of the telescope that if measurements of structures only ½ second of arc in size are sought, the equivalent focal length cannot be less than 10.3 meters and preferably should be three or four times this value, if one makes a reasonable provision for ease of observation. Experiments at the McMath-Hulbert Observatory have demonstrated that focal lengths as long as 1 kilometer can be profitably used for fine structure studies.

The diameter of the telescope objective is fixed by the wave properties of radiation and the angular size of the smallest object to be observed. A telescope capable of forming an image of the sun on a scale of ¼ second of arc per 1/40 millimeter, or 10 seconds of arc per millimeter, using infrared radiation of wavelength 0.0025 millimeter, must have a diameter of 2.5 meters and a minimum focal length of 21 meters. It should be noted that the solar image produced by a telescope with a ratio of focal length to objective diameter equalling 21/2.5, or 8.4, is much "too hot to handle." The focal length must be increased, so that the same amount of energy is spread over a larger area, until instruments in the focal plane are not heated uncontrollably. Simultaneously, the increase in the size of the sun's image makes it easier to study small structures.

Conclusion

These are some of the fundamental reasons why a very large telescope is required for significant progress in the study of fine structure on the sun over a broad wavelength range. A solar telescope with an aperture of a meter, or several meters, and a focal length of the order of 100 meters does seem to be a practical possibility. Accompanied by a properly matched spectroscope of modern design, it would constitute a research tool more nearly adequate than any existing instrument for dealing with the questions raised by the presence of the line details shown in Figs. 3–6, and the completely baffling correlation of these formations with the brightness of the sun.

Indeed, a very large telescope for the study of the sun would not only make possible observations of solar fine structure when the earth's atmosphere is "well-behaved," and good definition is possible; even under unfavorable conditions it would enormously extend the attainable precision and productivity in nearly all fields of solar physics now investigated with smaller instruments.

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Controlled-Climate Facilities for Biologists

Readers are asked to consider the feasibility of constructing what the authors term a "biotron."

S. B. Hendricks and F. W. Went

Knowledge of the effects of the environment on the growth and development of plants and animals has come from two different approaches: (i) observations in the field and (ii) laboratory experiments. Field observations are very difficult to interpret because of the complexity and nonreproducibility of the many climatic variables, whereas in laboratory experiments only a single environmental variable can usually be studied. To bridge this gap, it is necessary to have laboratory facilities in which the whole range of climatic variables may be controlled individually so that the interaction of these variables on the organisms can be assessed.

The first facility for the study of plant growth under a wide range of controlled conditions was constructed at California Institute of Technology in Pasadena, in 1948–49. This facility was dubbed a "phytotron" in a humorous moment, but the term was so appropriate that it has endured. The variables under control are chiefly ranges of temperature, light intensities, and cycles of these variables.

The Pasadena phytotron has been fully described elsewhere (*1*), and the results obtained through its use are in the literature. The phytotron has been generally accepted as an experimental tool, comparable to telescopes, particle accelerators, fossil collections, and other tools of science. Interest in such facilities, although it comes predominantly from plant scientists, has also been expressed by others experimenting with animals; thus the concept of a "biotron" developed.

A question naturally arises with regard to a successful experimental tool: How might it be made more widely available? With regard to a biotron, as well as other experimental tools, this is a complex question, involving enthusiasm, needs, effort and cost, the interest of groups of individuals, and the degree to which the community of biologists can afford to support the tool.

That interest in phytotrons became widespread is shown by the increased number of applications to the National Science Foundation for funds to construct controlled-environment facilities. Because of this interest, the foundation, in 1957, requested the American Institute of Biological Sciences to report on the need among biologists for such controlled-environment laboratories and to advise the foundation about the criteria on which applications should be judged. The findings included the realization that two needs existed: (i) individual growth chambers to create reproducible experimental conditions and to obtain uniform plant material and (ii) large facilities in which the effects on plants of different climatic variables could be studied simultaneously.

Since the report of this committee was not explicit about the most desirable size of a phytotron, or about the specific needs for one or more phytotrons in different regions of the United States, another committee was created to study specifically the feasibility of biotrons, including not only botanical but also zoological needs. This committee, financed by the National Science Foundation under contract with the Botanical Society of America, consisted of S. B. Hendriks, P. J. Kramer, C. S. Pittendrigh, C. L. Prosser, A. J. Riker, and F. W. Went, with Arthur Hess, who was responsible for the mechanical design of the Pasadena phytotron, as a consulting engineer.

The committee, to discharge its first obligation of sensing the level of enthusiasm, encouraging cross-talk, and imparting such information as it had, met early in May 1958 with small groups of biologists in four sections of the United States. Some of the pertinent points and issues raised are presented here, with the intention of informing anyone who might be interested in constructing a facility or in sharing in the effort with others.

Factors To Be Controlled

The factors of environment that were widely considered desirable for bringing under controlled variation were light, temperature, insolation, humidity, and cycles. Other factors that might require attention were the nature of media (composition of air, salinity), pressure (both air and hydrostatic), ionizing radiation, air ionization, and movement, as of air and stream flow. To attain many levels of these variables in the possible combinations was recognized as requiring a large facility. Accordingly, these types, as well as more limited arrangements, were considered.

A first and specific requirement of a phytotron is control and availability of high-intensity light. This necessitates the use of accessory glass houses using solar radiation and of considerable cooling capacity for controlled rooms. Plants generally can be housed together, but in the case of animals separate consideration has to be given to various classes. Animals would chiefly share with plants the requirement of temperature variation in the environment which might be affected by common controls. They might require gradual change, sinusoidal perhaps, instead of the abrupt ones used with plants.

Dormancy problems, for instance, of both plants and animals would have similar temperature and cycling requirements. Ancillary equipment for gas analysis, irradiation in limited spectral regions, production of high humidity, or control of wind velocity, as examples, could often be met in common.

The considerable size of a possible installation, the mechanical and electrical services required, and the use of ancillary equipment forced early consideration of meeting the needs for studies on both plants and animals in one structure, despite some of the obvious drawbacks. General agreement was expressed that some degree of combination would be desirable not only for economic reasons but also for the cooperation and stimulation that results from having botanists and zoologists work together. At one extreme was a single structure with separate parts for environments for plants and animals. At the other extreme were smaller biotrons adapted only to plants or animals and devoted to more limited studies. An intermediate position, which was often stated, was to put major emphasis on either plants or animals, with minor attention to the other.

At these meetings it was obviously impossible to get complete representation of research biologists, but an attempt was made to have at least some representatives of the botanical, zoological, agricultural, phytopathological, and other fields. Whereas the botanists made it clear that controlled conditions are an absolute necessity for the solution of many of their problems, the zoologists seemed to feel less urgency in their needs. However, all the zoologists agreed that they could make use of the facilities if available, and there is little doubt that, once they start, the field will develop as it has in botany.

Problems for Study

Among the problems most generally brought up for study in a biotron were the following: temperature and photoperiod effects, general interaction of environmental factors, rhythmic and cyclic studies, germination, separation of genetic and environmental effects, mechanisms of adaptation, acclimation, evolution, speciation, dormancy, and hibernation. Others such as radiation effects, hormonal control, mitosis and meiosis studies, environmental effects on plant pathology, life-span studies, and some marine problems were also considered.

Design and Location

Many questions of design require consideration. Are the plants and animals to be placed in one compartment for the duration of an experiment and the environment varied as desired within this compartment? This is to be weighed relative to shifting the experimental subject from chamber to chamber as is done, in part, in the Pasadena phytotron. A design for a phytotron in Canberra, Australia, has been drawn up after the first of these patterns, in which about 300 small cabinets are to be used.

The clean-cut distinction was sometimes missed between controlling the environment and study of the effects of its variation. The former is desirable in many cases and is widely used in the growth of plants where interest centers, for instance, on reproducible conditions for nutrition or the effects of herbicides. Many animal colonies are maintained under fixed conditions both for standardization and control of disease. But these types of installations are outside the present consideration because they are more easily attained. When the distinction was realized, a desire was nevertheless expressed to encourage the production of some type of standard chamber.

Types of possible locations were discussed. It was generally agreed that any installation should be on a campus to benefit fully from existing facilities and

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academic associations. The location should be one accessible by travel over short distances from one or more additional universities. This is to encourage use of the facility by groups of individuals during sabbatical years and nonteaching periods. To this end, some residential quarters would be desirable.

Conclusion

To complete the first phase of the work of the Biotron Committee it would be desirable to get further expression of the needs and specific requirements from biologists all over the United States. To this end, the Biotron Committee invites suggestions and ideas pertinent to the planning of national biotron facilities so that no possibilities will be overlooked. The committee is specifically charged with the investigation of large-scale facilities and should not primarily concern itself with individual controlled-environment chambers. Thus far our considerations have been completely independent of actual cost. It is assumed that, provided that the need for biotron facilities is unequivocally demonstrated, funds will be forthcoming.

To assist the National Science Foundation in arriving at realistic cost figures for biotrons, the committee is now drawing up preliminary designs for a large installation in which studies of environmental effects on both plants and animals can be undertaken. It is also intended to design an installation for small nonaquatic animals as a prototype. A modification of the Pasadena phytotron to incorporate the experience gained through its present operation and to permit some studies of animals will be undertaken. In this last case, attention will center on the possible application to ecology since the degree of interest is great. Finally, design of some type of box units will be considered. These designs will be available, in the final report of the committee, to groups that are interested in creating such facilities.

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European Science Museums

A tour shows how they cope with the problems of displaying famous apparatus of the past and present.

Robert P. Multhauf

Among the many treasure houses of Renaissance Florence still to be seen in that city is one easily overlooked by the uninitiated visitor, although to reach it he has but to proceed to the Arno through the court of the Ufizzi Gallery and turn left to the rear of that building. Here is the Palazzo Castellani, once the residence of the Podesta of Florence and now the home of the Museo di Storia della Scienza. Here the visitor can wander through quiet rooms housing the fragile three-century-old glass apparatus familiar from the pages of the *Saggi* of the Accademia del Cimento, the first scientific academy in Europe—a forceful reminder that the *Saggi* and similar publications are not the sole evidences of the work of the busy experimenters of the nascent age of modern science.

The oldest collection of apparatus displayed here is the legacy of the house of Grand Duke Ferdinand II, where these relics of the curious hobby of the illustrious ancestor rested quietly for a century after his death until their first exhibition in 1775. As a result of subsequent accretions in the course of its evolution into the *museo* of today, this is a somewhat motley collection, including, as well as some apparatus illustrated in the *Saggi,* mechanical, electrical, and pneumatic apparatus for the demonstrations dear to the heart of the 18th century scientific enthusiast and the telescopes and microscopes favored by connoisseurs of baroque craftsmanship. Many of these pieces came from other early Italian centers of scientific activity and were acquired in 1929, at the time of the National Exposition of the History of Science. Relics of such distinguished Italian scientists as G. B. Amici, Felice Fontana, and Paolo Mascagni comprise the bulk of these collections.

The fever of enthusiasm for experimental natural philosophy which spread across 17th century Europe has left material traces elsewhere, in museums and, increasingly rarely, in private collections. An air pump of von Guericke can be seen in Munich (at the Deutsches Museum) (*1*). The Boyle-Hooke pumps have been lost, but an early pump modeled after Boyle's first one can be seen in Leiden (at the Netherlands National Museum of the History of Science), and the fashionable designs of the Abbé Nollet and of Senguerd can be seen in many places. The earliest electrical machines seem not to have survived, but many examples remain from the flowering period of electrical experimentation, among the most notable being Hawksbee's (in the collection of the Royal Society of London) and the great machine of van Marum, in Haarlem (at the Teyler museum).

The optical and mechanical preoccupations of the age are similarly represented. The telescopes of Galileo in Florence and the reflector of Newton in London (in the collection of the Royal Society)are only the most famous of the many telescopes preserved. Of the very large instruments, understandably, scarcely anything remains, although the barrel of Herschel's great reflector still exists at the Observatory House, Slough, England. The pre-, or anti-, telescopic observers have also left few relics, although instruments associated with the name of Brahe exist in Kassel, Munich,

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and Prague. Some of the instruments from the early days of the observatories in Paris and London remain, both at the old observatories themselves and in the respective national museums (the Conservatoire Nationale and the Science Museum).

Examples of that other epoch-making optical instrument, the microscope, abound in European museums in the multitude of forms dictated by utility, economy, and style. An original Leeuwenhoek instrument can be seen at Leiden (*2*) as part of an excellent historical display of instruments by Leeuwenhoek and other early makers. Early examples of the work of the famous English makers of commercial microscopes are especially evident in the English museums.

In mechanics, much remains from the period of the spread of Newtonianism, in the form of more or less elegantly constructed demonstration apparatus, sets of pulleys, inclined planes, and the like. Perhaps the oldest set preserved is that made by the Musschenbroek family, in Leiden. The mechanical clock, displayed to show its works, can be seen in many places, notably in the well-kept Huygens room at Leiden, where one finds some of Huygen's original timepieces and replicas of others. At Greenwich (at the National Maritime Museum), the four chronometers of John Harrison tick again, and the Kassel Landesmuseum boasts a clock by Joost Bürgi.

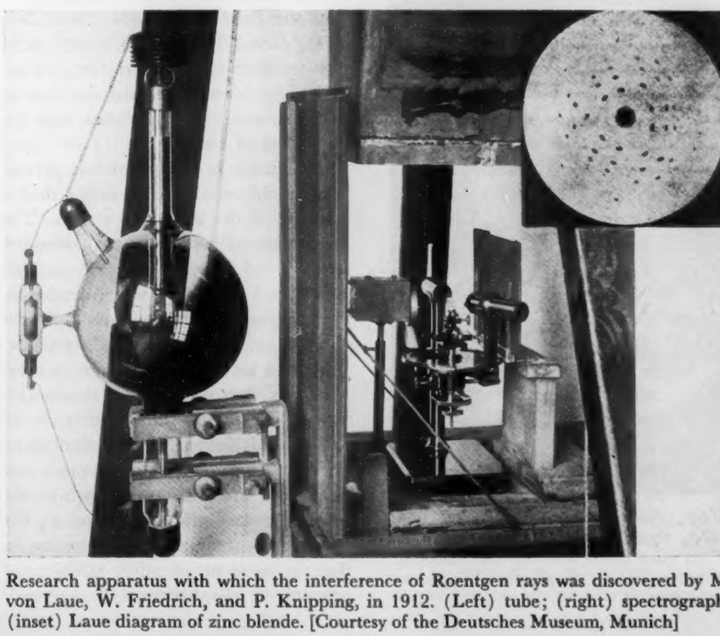
Most of the older museums are relatively small and fail, understandably, to maintain the richness of their collections far into the 19th century. That century saw the rise of national museums of science, notably in France and England, where an attempt was made not only to continue the preservation of scientific and technological relics but to provide a home for such of the earlier materials as were in danger of being lost. The national museums have grown to a size discouraging to the visitor with limited time. This disadvantage, however, is merely a reflection of the corresponding expansion of science itself. Today most of these museums are engaged in programs of renovation in an effort to differentiate the reference collections of interest chiefly to the specialist from the halls designed to appeal to the general visitor.

In addition to the museum in Florence, I visited a number of the other museums in Europe in the course of the tour upon which this article is based (*3*).

Paris: Conservatoire National des Arts et Métiers

The Conservatoire National des Arts et Métiers was created in 1794, by order of the National Convention, as a school for study of the applied arts and sciences. A collection of machines was assembled, notably those used by Jacques de Vaucanson (who died in 1782) for the training of workmen. Its existence as a significant science museum dates from 1814, when great quantities of scientific relics were received. Through the 19th century, apparatus was steadily added, much of it through the initiative of some of the great personalities of French science. From time to time other outstanding collections were acquired, such as that of the Académie des Sciences, in 1866. Since 1799 the Conservatoire has occupied the 11th-century

Alchemical laboratory of the 16th century. Full-sized reconstruction in the Deutsches Museum, Munich. [Courtesy of the Deutsches Museum]



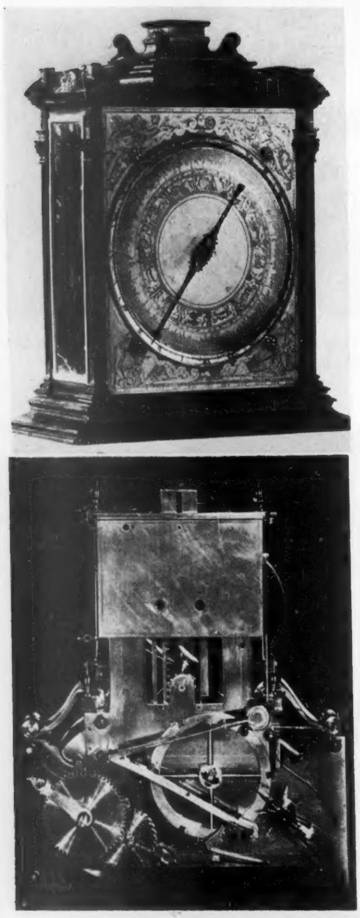
Research apparatus with which the interference of Roentgen rays was discovered by M. von Laue, W. Friedrich, and P. Knipping, in 1912. (Left) tube; (right) spectrograph; (inset) Laue diagram of zinc blende. [Courtesy of the Deutsches Museum, Munich]

Benedictine priory in Saint-Martin-des-Champs. Its quaint halls have long since suffered the overcrowding which tends to convert a museum into a warehouse, and today even the historian of science is likely to feel the onset of museum fatigue as he peers down its long corridors of massed cases. The critic would do well, however, to remind himself that here, more than anywhere else, have the *sine qua non* of a museum of science, the materials themselves, been preserved. The mute testimony of this museum speaks more emphatically of the seriousness with which science has been cultivated in France than many a eulogistic literary account of *la science française*.

The scientific collection is rich for the end of the 18th century, especially in the odds and ends of scientific work; in the field of optics, for example, the catalog lists 68 mirrors, prisms, and lenses received in the initial collection of 1814, not counting those which are parts of instruments. If it can be assumed that most of these represent the 18th century (the catalog is unfortunately of no assistance here), it would appear that this museum constitutes the richest source of working—as opposed to decorative—apparatus from that century.

Although associated from its origin with a school, this is fundamentally a study collection for specialists. The use of scientific exhibits for teaching, which has been initiated in the museums of Germany, Austria, and Sweden, has been undertaken in France through the establishment of a separate museum, the Palais de la Découverte.

Among the more spectacular items in the scientific collections are the highly decorative apparatus of Abbé Nollet, comprising one of the most interesting examples of the scientific cabinets esteemed by the wealthy 18th-century amateurs of science, and, scarcely less ornamental, the original apparatus of Lavoisier. Less decorative but no less interesting are the original refrigeration apparatus of Carré and Cailletet's apparatus for the liquefaction of gases.



(Top) An observatory clock of Joost Bürgi, about 1590; (bottom) rear view of the same clock, with the case removed. [Courtesy of the Hessisches Landesmuseum, Kassel]

Paris: Palais de la Découverte

The Palais de la Découverte had its origin in the scientific exhibits shown in connection with an international exposition, the Paris fair of 1937. Established in the Grand Palais, itself a survival of another international exposition, the exhibits have been maintained and kept up to date through an association with the University of Paris.

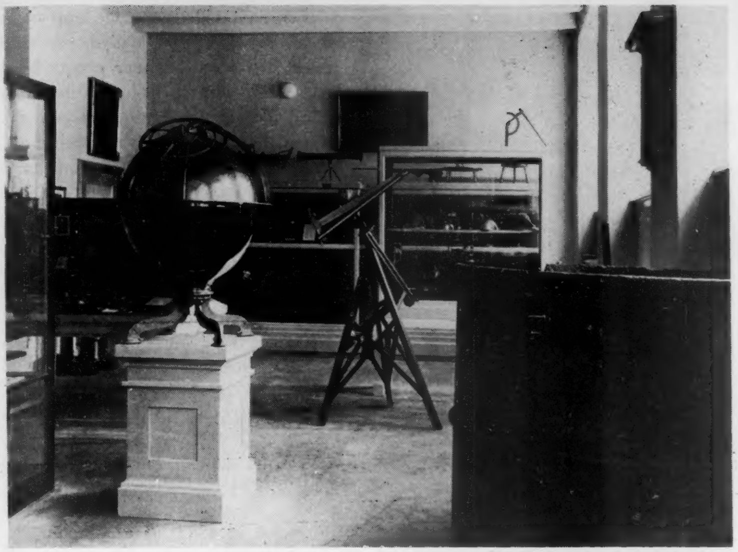
The Palais is a more or less permanent exhibition of science rather than a museum of the history of science. The conception of setting up an animated textbook of science—or perhaps one should call it a laboratory extended in space rather than time—has been carried out in varying degrees elsewhere, but never on so grand a scale as here, where one may see animated demonstrations not only of the experiments of Galileo and Newton but also of those of de Broglie (undulatory mechanics) and Langevin (ultrasound). Although its objectives are not primarily historical, the Palais has encountered the necessity, in the arrangement of such exhibits, of bringing in the historical background, and some of the exhibits are highly historical in character. Little effort, however, is made to emphasize historic apparatus.

So comprehensive a display requires a vast allotment of space, and the Palais is vast, although it occupies but a minor portion of the Grand Palais. It also requires curatorship of a highly specialized character, and this it is able to obtain by virtue of the relationship existing with the University of Paris. One may surmise that the feasibility of maintaining such an exposition depends upon its location in a great metropolis near the geographical center of the country.

London: Science Museum

Following the Great Exhibition of 1850, a proposal was made by the Prince Consort for the establishment of a museum of science. The consequent plans were implemented in 1857 through the establishmnt of the South Kensington (after 1899, the Victoria and Albert) Museum, wherein were exhibited, among a great many other things, collections illustrating foods, animal products, building materials, and educational apparatus. The Science Museum in its present form originated in the famous 1876 Special Loan Exhibition of scientific apparatus, much of which was subsequently acquired by the museum. Fortunately, historic apparatus and machinery had been sufficiently esteemed in England to make possible the assembly of an extraordinarily complete series illustrating the development of the sciences and technical arts; this collection has occupied independent quarters, under the name of the Science Museum, since 1909.

In 18th-century materials this museum appears to be less rich than the Conservatoire in Paris. Through successive enlargements of its quarters, however, the Science Museum has succeeded to a degree not equaled elsewhere in encompassing the 19th century. Only here can the student of technology in its ebullient adolescence expect to find a sufficient representation of the successive development of machines to serve as an adequate record of that prolific century. Science is nearly as well covered, although its relatively less materialistic character is reflected in the collections. The most comprehesive group of instruments is the "King George III" collection, so-called because of its connection



A portion of the Astronomisch-Physikalische Kabinett of the Hessisches Landesmuseum, Kassel. Shown are (left to right) a celestial globe of Joost Bürgi (1585), an astronomical sector of John Dolland, and the steam-engine cylinder attributed to Denis Papin. [Courtesy of the Landesmuseum]

with that monarch. The collection comprises over 300 instruments, the principal part of which was assembled from 1740 to 1768 by Demainbray, a tutor to the royal family. Many of the instruments are designed to demonstrate Newtonian philosophy as expounded in Desaguliers' *Experimental Philosophy*—in fact, some of them may have been built by Desaguliers himself. George Adams is, however, the principal constructor represented. Notable among the later materials are original apparatus of Ramsden and other founders of scientific surveys; apparatus of Graham, Ramsay, and other British chemists; and electrical materials from researches of the later 19th century. By no means all of the historic scientific apparatus in London has gravitated to the Science Museum. Hawksbee's vacuum pump and Newton's reflecting telescope are in the library of the Royal Society, and a considerable number of relics of the scientific work of the luminaries of the Royal Institution (such as Rumford, Davy, Faraday, Tyndall, and Dewar) are on display in that venerable institution. A very handsome display of instruments is also to be found in the Navigation Room of the National Maritime Museum, Greenwich.

As it has to all technical museums, the 20th century has presented a formidable challenge to the ingenuity of the staff of the Science Museum. The vast sequences of instruments and machines which have long been the resort of the student of technological development are in danger of termination through lack of space. Whereas most of the earlier materials are original, the machines of today are often represented by models or demonstration exhibits. A new wing is under construction, but the new exhibits are, out of sheer necessity, forced into a pattern similar to that introduced in Munich and Vienna, in which the history of a science or art is ancillary to an exposition of principles, or at best is presented in its main lines, at the expense of the subtleties which the specialist seeks for further elucidation of a story he already knows.

Oxford: Museum of the History of Science

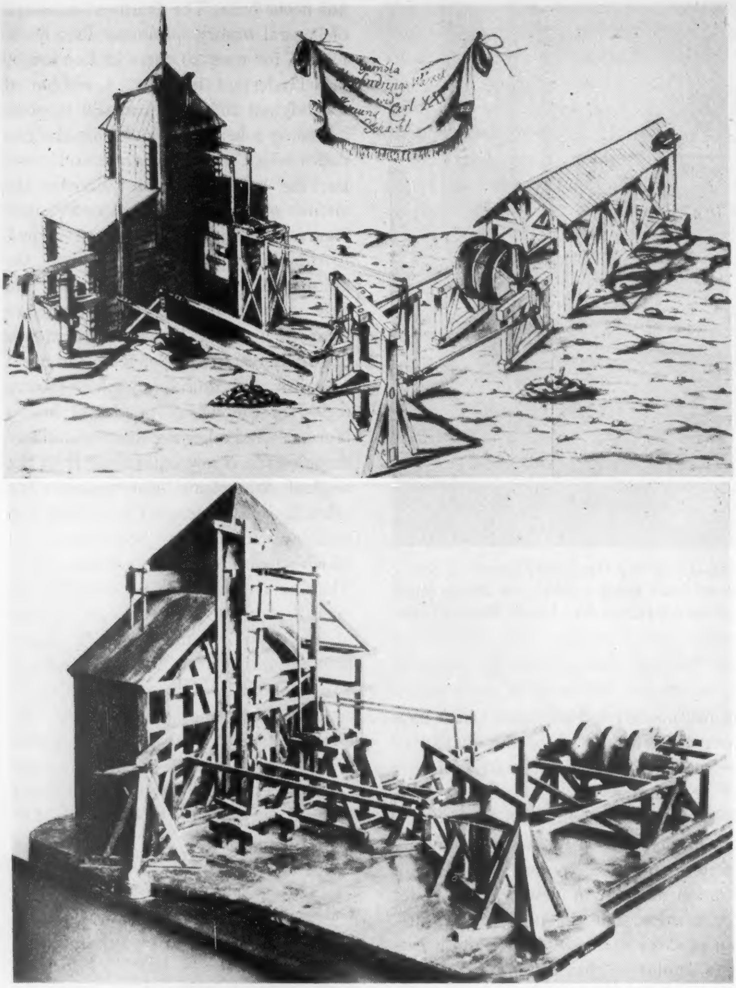
Possibly the most impressive single collection of antique scientific instruments, the Museum of the History of Science, in Oxford, had its genesis in the bequest to Oxford of the collections of Elias Ashmole. "Mr. Ashmole's Rarities" were put on exhibition in 1683 in the present building, adjacent to Wren's Sheldonian Theatre, a building which is supposed to have been influenced in design by the College of Science planned, by Wren, for construction in London, but never built. The "rarities" consisted of natural history specimens already exhibited for over 20 years in London by the Tradescant brothers. A residue of the original collection can still be seen, including a head and foot from the two dodos which once graced the collection, but the "rarities" were otherwise the victims of one of the most unfortunate "house-cleaning" operations on record.

Although originally a museum, the building has had a varied career and only assumed the form of the present museum in 1949. The lower room was originally fitted as "one of the most beautiful and useful [chemical laboratories] in the world," and still houses "furnaces and other necessary materials," though little if any equipment from the original Ashmolean "elaboratory." The other floors are occupied by various outstanding subsequent acquisitions, of which only a few can be mentioned here. The Orrery collection, assembled by the great-nephew of Robert Boyle, consists of about 20 instruments, chiefly astronomical, dating from between 1658 and 1710. The Lewis Evans collection of astrolabes and sundials contains the largest collection of the former ever assembled in one museum. Other astronomical collections derive from the Royal Astronomical Society and from Radcliffe Observatory.

Cambridge: Whipple Museum; Museum of the Cavendish Laboratory

The Whipple Museum of the History of Science, in Cambridge, was organized in 1949, on the basis of a sumptuous collection of instruments assembled by Robert Whipple of the Cambridge Instrument Company between 1919 and the date of its presentation to the University of Cambridge. Especially noteworthy in this impressive exemplification of the possibilities which existed so recently in scientific-instrument collecting are an 8-inch reflecting telescope made by William Herschel about 1800 and two refractors made by Christopher Cock, the maker of Hooke's microscope. There is also an original Cock microscope, part of a large and continuous series of microscopes dating from 1650 to 1850. Interesting also is a set of geometric models, by George Adams, to illustrate Euclid's books xi and xii on solid geometry.

The number of instruments originating in Cambridge does not appear large



Christopher Polhem's ore conveyor, as used in the "Charles XII shaft," Falun, Sweden; drawing (top) by Samuel Sohlberg and model (bottom) in the Tekniska Museet, Stockholm. [Courtesy of the Tekniska Museet]

—perhaps a reflection of the newness of the museum. A most impressive showing of Cambridge instruments is, however, to be seen in the halls of the Cavendish Laboratory. Here are exhibited original equipment from Maxwell, Rayleigh, J. J. Thomson, C. T. R. Wilson, Lord Rutherford, and F. W. Aston, probably the most notable assemblage of relics of the history of modern physics to be found anywhere.

Vienna: Technisches Museum für Industrie und Gewerbe

The inclusion of both scientific and technological materials, which characterizes the national museums in Paris and London, despite the differences in their titles, is to be found to a lesser degree in the Vienna museum. More than any other museum, this one attempts to cover in its exhibits the entire range of technical subject matter, including fields, such as the technology of food production and processing, which are very sketchily touched upon elsewhere. The museum opened in 1918, after a natal period of 45 years, during which time various independent museums of railways, post and telegraph, and industrial hygiene came into being and were integrated into the plan for the Technisches Museum.

While the fundamental purpose of the museum appears to be the exposition of the principles of contemporary technology, reliance for the accomplishment of this has been placed upon the illustration of its historical development, and upon the use of operating and demonstration models. This would appear to have been the first museum to utilize visitor participation extensively. In the physical sciences the majority of the exhibits are demonstration experiments performed by guides at standard laboratory tables, the historical approach being utilized to a lesser degree than in Munich. The quantity of historical materials exhibited is also considerably less, a fact which is presumably attributable in part to the existence of two fine collections of antique instruments elsewhere in Vienna, the cabinets of the Kunstgewerbe and Kunsthistorisches museums.

Munich: Deutsches Museum

Founded in 1903, as a museum "to show the great influence of scientific research on technology and the historical development of the various industries," the Deutsches Museum of Munich recently celebrated its fiftieth anniversary, having survived World War I, which delayed its opening until 1925 (although portions of the collection had been exhibited much earlier in the Bavarian National Museum), and World War II, in which it suffered the destruction of most of its exhibit halls through bombing. On the credit side, it is perhaps worth mentioning, as noted in the anniversary publication, that World War II may have saved the museum from the increasing pressure of the Nazi party to divert its purposes to other ends (*4*).

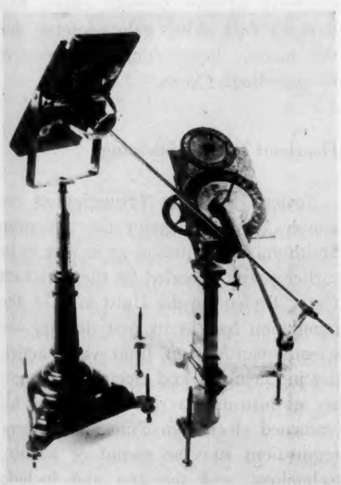
Like the Technisches Museum in Vienna, the Deutsches Museum was designed to instruct in the principles of science and technology as well as to show the history of science and technology. The latter museum has led in the art of the cleverly contrived push-button exhibit and, since the war, in the replacement of strictly utilitarian exhibits with elegant and sometimes spectacular displays which seek to exploit the beauty as well as the technical interest of the machine. This new concept of display, which was anticipated in the Stockholm Tekniska Museet, has had great influence on most of the other technical museums. On the debit side, it involves a reduction in the number of specimens on exhibit.

The hall of physics was very nearly the only one to survive the war intact, and it remains in its original condition, an interesting example of prewar museum technique in this otherwise new

museum. The hall of chemistry is new; halls of astronomy and geodesy are partly completed. The over-all reconstruction of the museum was about half completed in the spring of 1956.

The outstanding original scientific specimens in the museum are in the hall of physics. Here one can see von Guericke's air pump and the famous Magdeburg hemispheres, Ohm's static electric machine, Meyer's calorimeter, Hertz's resonators, the telegraphic apparatus of Soemmering and Steinheil, and von Laue's apparatus for x-ray interference. The great refractor built by Frauenhofer for the Pulkowa Observatory in 1838 may be seen in the astronomy section, and the work table of Otto Hahn in the section devoted to chemistry. Unlike the corresponding museums in London and Paris, the Deutsches Museum has many reproductions of apparatus, in part because it got off to a late start in collecting, but principally because any attempt to use historic apparatus systematically in an exhibit of the history and principles of science must inevitably involve finding some way to solve the problem of the nonavailability of all of the important objects which should be shown.

A feature of the exhibit of chemistry is a "family tree" of important chemists who were, directly or indirectly, associated with the laboratory of Liebig at Giessen. A visit to this laboratory, which is still preserved at Giessen in a convincing approximation of its original state, must be a high point of any chemist's tour of European museums. Nonchemists, too, should find it a worth-while experience, for, so far as I know, nowhere else is such a thoroughgoing attempt made to preserve the environment of the scientific laboratory of a century ago.



Heliostat with clockwork, invented by s'Gravesande and constructed by Jacob van der Cloese at Leiden. Height to mirror axis, 35 cm. [Courtesy of the Rijksmuseum voor de Geschiedenis der Natuurwetenschappen, Leiden]

Exhibit of globes in the Museo di Storia della Scienza, Florence. The ornate armillary in the center was made by Antonio Santucci in 1588–93. [Courtesy of the Museo di Storia della Scienza]

The Giessen Museum comprises the famous teaching laboratory and amphitheatre, gross preparation rooms, library, and Liebeg's study, all well set out with apparatus. So great was Liebig's influence on the laboratory teaching of chemistry that his laboratory does not appear especially out of date when compared to many in our own colleges, at least of the period up to World War II.

Kassel: Hessisches Landesmuseum

The Astronomisch-Physikalische Kabinett in the Kassel Museum represents the longest continuous period of history of any large collection in Europe, having had its beginnings in the astronomical interest of Landgraf Wilhelm IV just after the middle of the 16th century. His observatory was visited by Brahe in 1575, and a portable quadrant which remains from that time may have been constructed after Brahe's advice. Another famous visitor, Joost Bürgi, was engaged as royal clockmaker in 1579 and has left several examples of his work. Other relics remain of the scientific interests of subsequent landgraves—interests which were not uniformly physicoastronomical—and from Johann Christian Breithaupt, 18th-century founder of the scientific instrument industry in Kassel. Most of the later materials shown are demonstration apparatus from the late 19th century, from the Kasseler Hohern Gewerbeschule, the academic home, at various times, of Wohler, Bunsen, and Kohlrausch. As most purely scientific collections contain a few odds and ends of "pure" technology, this contains an iron cylinder described, although not without some reservation, as the remains of a steam engine deriving from another notable visitor to Kassel, Denis Papin. If authentic, it is the oldest existing relic of the steam engine.

Kassel, one of the most ill-fated of German cities in the late war, has made a remarkable recovery, but the scope of the reconstruction task is stupendous, and only a portion of the above-mentioned collection was visible in 1956 in the reconstructed Landesmuseum. A few unspecified large items are said to have been destroyed during the war, but the bulk of the collection, and all of the most important items, seem to have survived.

Certain instruments were built in the Kassel workshops in the time of Wilhelm IV for the Kunstkammer of his fellow

monarch Kurfürst August I of Saxony (who died in 1586). These instruments and others, constituting one of the finest collections of this type, were exhibited before the war in the Zwinger Pavillion in Dresden. I am informed that all or some of them are again on display in Dresden. This collection included over sixty items from the 16th century and contained apparatus from Kircher, Schissler, and Leupold.

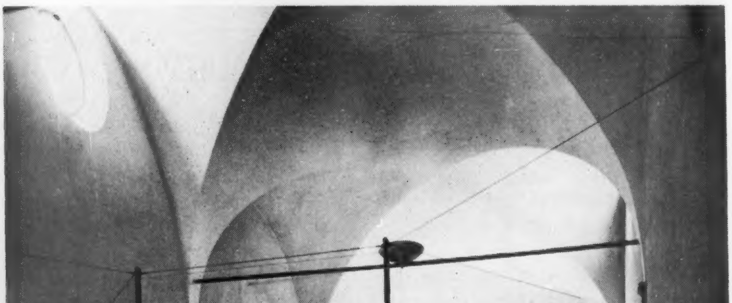
Stockholm: Tekniska Museet

Opened in 1938, after 14 years of planning and organization of financial support, the Tekniska Museet in Stockholm is in many ways the most remarkable of the national museums of science and technology, being largely, if not completely, privately supported and serving as a general repository for the archives of Swedish industries.

More nearly than in any other museum except for the Technisches Museum in Vienna, the exhibits here comprehend the entire range of technology. Emphasis is on modern technology in most of the topical exhibit halls, historical materials being chiefly shown in commemorative displays of various Swedish inventors, such as Polhem, De Laval, and Ericsson. Some of these halls are especially interesting from the point of view of exhibition technique, in the development of which this museum has been particularly active.

The Kungliga Modell-Kammaren, a collection of about 250 models of machines from the period circa 1700, is of special interest for the unique evidence it furnishes of the work of the engineer of that period. Most of the models derive from Christopher Polhem, Sweden's outstanding early mechanical genius.

The exhibits in physical science are largely instructional rather than historical in character (5). Outstanding among these is the "Atomarium," a hall devoted to operating exhibits and lecture demonstrations of atomic science.



Entrance to the hall in the Museo Nazionale della Scienza e della Tecnica, Milan, in which drawings and models illustrating the work of Leonardo da Vinci are exhibited. [Courtesy of the Museo Nazionale della Scienza e della Tecnica]

Leiden: Rijksmuseum

Leiden's Rijksmuseum voor de Geschiedenis der Natuurwetenschappen, founded in 1931 and given the status of a national museum in 1947, is one of the best known to historians of science through the excellent publications of its staff. Like the museums in Florence, Oxford, and Cambridge, it is particularly concerned with the history of science, and despite its relatively recent foundation, the Rijksmuseum has succeeded remarkably well in acquiring a really significant collection of historical materials.

The displays of the work of Huygens and of that of the Dutch microscopists are unusually well-conceived demonstrations of the possibilities of effective museum display of the history of science. Included here are original clocks, a telescope and lenses of Huygens, and an original Leeuwenhoek microscope. Also of special interest are the 'sGravesande-Musschenbroek apparatus for the demonstration of Newtonian physics and Leyden jars and a pyrometer from Petrus van Musschenbroek. The series of early air pumps at Leiden is probably the best to be seen anywhere. Certain instruments from important Dutch researches of modern times are also shown, such as the electromagnet used in the discovery of the Zeeman effect, Einthoven's first string galvanometer, and the helium liquefaction apparatus of Kammerlingh Onnes.

Haarlem: Teyler's Stichting

Teyler's Stichting (Foundation) resembles to some extent the American Smithsonian Institution as it was in its earlier years. Founded by the merchant Pieter Teyler van der Hulst in 1778, the foundation had as its first director the scientist van Marum, from whose activities in chemistry and electricity a number of instruments remain, notably his renowned electric machine. Subsequent acquisitions run the gamut of science, technology, and the arts and include many interesting items; the collection is somewhat lacking in systematic display but retains uniquely the atmosphere of the era which saw the genesis of the idea of the scientific institution.

Visitors to Haarlem, however peripheral their interest in technology, should not fail to visit the nearby museum of the Cruquis steam engine, near Heemstede. The museum is devoted to the history of land drainage in Holland, a story which it tells very well. It is built around a most remarkable Cornish steam engine, in which a high-pressure cylinder is located within, and concentric to, a low-pressure cylinder, the whole operating a series of eight rocking-beams which operate eight pumps arranged equidistantly around the circumference —truly a chef d'oeuvre of 19th century technology!

Milan: Museo Nazionale della Scienza e della Tecnica

The National Museum of Science and Technology of Italy is Western Europe's newest museum in this field, having been established in 1949 in the Monastery of San Vittore, Milan (*6*). The monastery, which was left in a ruinous condition by bombardment in World War II, has been elegantly reconstructed; the general form and some of the details of a monastery have been preserved, but the severely simple style of interior decoration characteristic of postwar Italy has been adopted. In its organization the museum follows a unique concept, the exhibition of the work of Leonardo da Vinci in the multifarious fields cultivated by him being taken as a point of departure for display of the subsequent development of the various sciences and technologies.

The difficulty of outfitting a technical museum at this late date is, understandably, reflected here. Not only is the establishment of exhibits a time-consuming process but the collection of suitable specimens is a matter of great difficulty. In the field of physical science, however, the museum has been most fortunate in acquiring a large number of instruments from the scientific collections of the University of Padua, many going back to the 18th century. Reproductions have also been made of a number of the instruments in the museum at Florence.

In the spring of 1956 these exhibits were in process of being installed, and were not on public exhibition. The most spectacular exhibit on public view consisted of finely made models constructed after the drawings of Leonardo. These models are beautifully shown in what must be one of the longest single halls in any museum. This museum will be spectacular indeed if that standard of exhibition is maintained.

Notes

1. Another of von Guericke's air pumps is reportedly at Lund, Sweden (see *5*).
2. Other Leeuwenhoek instruments are in Munich, Jena, Utrecht, Antwerp, and Paris. See P. van der Star, *Descriptive Catalogue of the Simple Microscopes* (Leiden, Netherlands, 1953), p. 24.
3. This tour was made in the spring of 1956 and covered all of the larger and most of the smaller museums of science and technology in Western Europe, with the exception of those devoted to particular sciences or technologies, such as medicine and pharmacy, horology, communications, transportation, and marine. Emphasis in this article is placed upon the scientific materials in the museums visited.
4. *Fünfzig Jahre Deutsches Museum* (Deutsches Museum, Munich, 1953), p. 16.
5. The principal collection of early scientific instruments in Sweden is that of Triewald, now at the University of Lund. Martin Triewald spent the years 1716–26 in England, returning to Sweden in the latter year to introduce the steam engine to that country. While in England he made the acquaintance of Newton, Desaguliers, and others, and assembled the collection of "philosophical apparatus" which is now at Lund. An original von Guericke air pump is also in the collection. See J. G. Tandberg, "Die triewaldsche sammlung . . .," *Lunds Univ. Arsskr.* 9 (1920).
6. A predecessor existed in Turin as early as 1862 but had been relatively inactive in the 20th century and suffered the loss of most of its remaining collections in World War II.

Arda Alden Green, Protein Chemist

Arda Alden Green had a remarkable record of achievement in biochemistry. This record was only recently recognized by the American Chemical Society, which, at its September 1957 meeting in New York City, announced that she would be the next recipient of the Garvan Medal, the highest honor accorded for achievement in chemistry by an American woman. The citation for this award, which was presented posthumously at the April 1958 meeting of the society in San Francisco, reads as follows: ". . . for her many contributions in the field of protein isolation and characterization, including her classical studies on hemoglobin, the plasma proteins, the muscle enzymes and the enzymes responsible for bioluminescence."

Arda Green was born in Prospect, Pennsylvania, on 7 May 1899. She obtained her A.B. degree in 1921 at the University of California in Berkeley, where she received highest honors in chemistry and honors in philosophy. After one year of graduate study in philosophy, she decided to study medicine. During her first two years of medical studies at Berkeley, she became acquainted with Herbert M. Evans, who recognized her potentialities and encouraged her to interrupt her medical studies in order to spend a year in research at Harvard University Medical School, in the laboratory of Edwin J. Cohn. Evans was instrumental in obtaining for her the Leconte memorial fellowship of the University of California, which she held during the year 1924–25.

She spent the following two years at Johns Hopkins University, where she completed her medical studies and obtained the M.D. degree in 1927. While a medical student there, she became acquainted with Leonor Michaelis, then a biochemist in the department of medicine, and did some research in collaboration with him and A. A. Weech on the conductivity of electrolytes within membranes, a study which became the subject of her first publication.

She then returned to Cohn's laboratory at Harvard as a National Research Council fellow in medicine for the period 1927–29. During this period she completed her classical studies on the equilibrium between oxygen and hemoglobin and its relation to changing hydrogen ion activity. These studies, carried out in collaboration with Ronald M. Ferry, had been initiated in 1924 during the tenure of her Leconte memorial fellowship. They served as the

basis for some of Pauling's views on the structure of hemoglobin.

During the next 12 years, 1929 to 1941, she remained at the Harvard Medical School, for the first five years as a research fellow in the laboratories of Cohn and L. J. Henderson, and for the next seven years as a research associate in pediatrics with C. F. McKhann. During all of this period she maintained a close association with the members of the Cohn laboratory and played an important role in the development by that group of its elegant methods for the isolation of the blood proteins. Of particular importance were her remarkably thorough studies of the solubility of hemoglobin under varying conditions of ionic strength and hydrogen ion activity. These studies, published in 1931 and 1932, remain today the best model for investigations of this kind and provided the basis at that time for the development of rational methods for fractionation of the plasma proteins by the Cohn group.

In the period 1933 to 1937 she published other fundamental studies on hemoglobin, dealing with its combination with carbon dioxide, its combination with carbon monoxide, and its amphoteric properties. During her period of collaboration with McKhann, she investigated the immunological application of human placental extracts for the prevention of measles and worked out fractionation procedures for the globulins of normal and immune sera. Her final publication in this period concerned the equilibrium between calcium and purified globulins and was carried out in collaboration with Nancy Drinker and A. Baird Hastings.

During this highly productive 12-year period of research activity she served, in addition, as tutor in biochemical sciences at Radcliffe College. In this type of teaching she was extremely effective, by virtue of her great sensitivity to the individual problems of her students as well as the beautiful clarity and incisiveness of her reasoning. During this period she exerted great influence in directing some of the women who were her students into productive careers in medical research.

The next important phase of her career was in the laboratory of Carl and Gerty Cori at Washington University (St. Louis) during the period 1941 to 1945, when she served as research associate in pharmacology. During the period 1942 to 1945 she also served on the faculty as assistant professor of biological chemistry. Here she was instrumental in introducing sound methods for the purification and characterization of the muscle proteins. Early in this period she developed the method for the isolation of the crystalline enzyme phosphorylase, thereby facilitating the elegant studies of Cori and Cori on the mechanism of polysaccharide synthesis, for which they received the Nobel Prize in 1946. It is noteworthy that she developed this method in the short space of ten weeks, after three other investigators in the same laboratory had devoted three fruitless years to the same problem. During this period she also collaborated with G. T. Cori and John F. Taylor in the crystallization of rabbit muscle aldolase. Her presence in the Cori laboratory at this particular time had a tremendous influence on the development of enzymology in this country, since many of the investigators who studied in that laboratory then or subsequently (Ochoa, Kalckar, Leloir, Kornberg, Najjar, and others) learned directly or indirectly from her the importance of enzyme purification in the elucidation of enzyme mechanisms.

She then joined the laboratory of Irvine Page at the Cleveland Clinic, where she served as a staff member in the research division from 1945 to 1953. Here her attention was drawn to the presence in serum of a vasoconstrictor substance, which she isolated and characterized in collaboration with Page and M. M. Rapport, in 1948. This substance, which they named serotonin and which was later identified by Rapport as 5-hydroxytryptamine, is, of course, recognized today to be of great importance as a regulator of the activity of the central nervous system. This accomplishment, which sparked what Woolley has termed "the revolution in pharmacology," illustrates that Arda Green's laboratory talents were not limited to the isolation of proteins.

While in the same laboratory she was concerned for several years with the purification of proteins believed to be involved in renal hypertension. She succeeded, in collaboration with F. M. Bumpus, in the extensive purification of renin substrate (hypertensinogin) from serum and of angiotonin (hypertensin), the pressor polypeptide which is released from hypertensinogin by the action of the kidney enzyme renin. She also worked hard but unsuccessfully on the isolation of the latter enzyme. In the course of this work, several unidentified crystalline proteins were obtained from hog kidney. The methods for obtaining these crystalline proteins have, unfortunately, remained unpublished.

In 1953 she joined W. D. McElroy at the McCollum-Pratt Institute of Johns Hopkins University, where she began her work on the purification of enzymes involved in bioluminescence. Her outstanding achievement in this area, announced in April 1956, was the successful crystallization of the enzyme luciferase from firefly lanterns. This work led to the elucidation of the role of adenosinetriphosphate, luciferin, and coenzyme A in light emission. The discovery of an adenyl-luciferin intermediate in the reaction established the basic similarity between the firefly enzyme reaction and the universally occurring enzyme reactions for the activation of acetate and amino acids.

Her last laboratory project was the purification of the enzyme responsible for bacterial luminescence. She had succeeded in purifying the enzyme extensively and had described its properties in 1955. However, she continued with her usual tenacity toward her goal of isolation of the protein in crystalline form, and no one can doubt that she would have had her usual success if time had not run out.

In addition to her research duties in the McCollum-Pratt Institute, she played an important role in the training of graduate students. This was due not only to her authoritative lectures on the proteins but, even more, to the warm personal relationship which she established with the students, who recognized her as a friend to whom they could bring both scientific and personal problems.

During this last phase of her career she served also as a consultant in biochemistry to the department of pediatrics of the Sinai Hospital. Here she exerted an important influence in guiding clinical research along sound biochemical lines.

Arda Green did not always receive the recognition which she deserved, partly because she always worked in the shadow of men of great scientific reputation. The uniformly high quality of her research over the years makes it clear that she had a unique talent which was responsible for her success in the isolation of pure proteins. Her success in this field was in part due to her conviction that the purification of proteins was a sufficiently important goal in itself to deserve a life-time of concerted effort. More important was her ability to consider problems of protein purification in a logical manner—an ability based on her broad

knowledge of their physicochemical properties. Many have attributed her success in crystallizing proteins to her "magic touch." Some even suggested to her that her secret lay in some mysterious seeding effect of the ash falling from the cigarette which never left her mouth when she was working. She enjoyed these jibes, but she felt very strongly that protein purification should be divorced from the mystery which is usually associated with it. She felt that it should be based, rather, on the application of "horse sense," an attribute which she admired in others and with which she herself was endowed to a remarkable degree.

Arda Green lived a full life outside of the laboratory. With the same vigor, enthusiasm, and thoroughness with which she attacked her laboratory problems, she devoted herself at home to cooking, dressmaking, music, and entertaining. It was she who always saw to it that no unattached members of the laboratory staff ever went unfed on Thanksgiving Day. Her genuine concern for others and her deep devotion to her family always showed itself not just in words but in practical, helpful gestures. Even during the crippling illness which marred the last year of her life she continued to devote herself to doing things for her family and friends, almost to the day of her death, on 22 January 1958.

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News of Science

Final Form of Congressional Action on Federal Aid to Education

Pursuing a course of action formally initiated by the President last January, the House of Representatives and the Senate have passed legislation which gives federal aid to the educational effort of the country. The two houses, working in a preadjournment flurry of activity, accepted separately two differing measures. These were reconciled in a conference meeting of the relevant House and Senate committees, and the final form of the legislation has now been elaborated.

Earlier House Action

On 8 August the House of Representatives, after lengthy and occasionally raucous debate, passed HR 13247, the National Defense Education Act, but not before the scholarship provision, one of the major elements of the bill, was eliminated. No funds, however, were subtracted from the bill. Rather, on a motion offered by Representative Walter H. Judd, (R-Minn.), those funds originally alloted for the scholarship provision were shifted to increase substantially the student loan fund provided for under title 3 of the bill. The effect, in short, was this: while federal expenditure for aid to education was to be at the same level as was called for by the original provisions, the money was to go out to students in the form of a loan, to be repaid after graduation, rather than in the form of a grant of money. This form, loan with repayment after graduation, is one currently in use by many colleges and universities.

Title 3 of the original bill—loans to students in institutes of higher education —read in part as follows: "For the purpose of enabling the Commissioner [of Education] to stimulate and assist in the establishment at institutes of higher education of funds for the making of low interest loans to students in need thereof to pursue their courses of study in such institutions, there are hereby authorized to be appropriated $40 million for the fiscal year ending 30 June 1959, $60 million for each of the three succeeding fiscal years, . . ." As passed by the House, title 3 called for an additional $20 million to augment each of the original appropriations, for a total basic loan fund of $300 million.

Earlier Senate Action

The Senate, ending debate on its form of the education bill at 12:05 A.M. on the morning of 14 August, passed a bill which retained, on a diminished scale, the scholarship program. By its approval of an amendment offered by Senator Cooper of Kentucky, the Senate reduced the cost of the program from $17.5 million to $5 million, by reducing the grants to individual students from $1000 a year to $250 a year. The 4-year program would have benefited about 23,000 students a year.

Reconciliation

On 21 August a compromise between the House and Senate measures was worked out in conference. This compromise constitutes the final form of federal aid to education legislation. It calls for a 4-year, $887,400,000 program with no scholarship provision. Aid to individual students would come from a loan fund of $295 million over a 4-year period. The fund is to be administered by the institution of higher learning at which the student studies, rather than by a state board as the Senate bill had stipulated.

In addition to the loan fund, the compromise bill calls for $300 million, to be matched by the states, for the purpose of helping schools, public and private, to purchase equipment for the teaching of scientific subjects.

The bill also authorizes funds for the following: institutes for teachers to learn educational counseling; centers for training foreign-language teachers; fellowships, including allowances for dependents of recipients; guidance, counseling, and testing for precollege students by the states; centers for teaching little-known modern languages; research and experimentation on better educational use of television, radio, and audiovisual aids; vocational education in skilled trades necessary for defense; and improvement of state educational statistics.

Both Senator Hill and Representative Elliot, the sponsors of the bills in the two houses, expressed some degree of satisfaction with the result of the compromise. But Senator Hill and Senator Smith of New Jersey deplored the loss of the scholarship provision and the corollary defeat of the attempt to give national recognition to intellectual achievement by means of it.

Merit or Need

Earlier forms of this legislation had reflected a variety of attitudes toward the question of the proper basis for awarding aid to the individual student.

Should need or merit be the deciding criterion? Bills that reflected the Administration view of the matter declared that financial necessity should determine the selection of recipients of aid, whereas the bills introduced by Senator Hill and Representative Elliot stressed the honorary element of the award by which the government recognized those students whose work showed high achievement at the high-school level.

The tenor of the earlier Hill-Elliot bill and its attitude toward the merit basis for award can be seen in the paragraph stating the purpose of the bill: "to strengthen the national defense, advance the cause of peace and assure the intellectual preeminence of the United States especially in science and technology. . . ." In addition to granting scholarships on a merit basis, the earlier Hill-Elliot bill called for Congressional citations to the top 5 percent of high-school graduates. None of these provisions with the general aim of increasing the prestige of intellectual activity succeeded in getting through the welter of Congressional debate. The need-or-merit problem was resolved in favor of need in two steps. First, it was proposed that the successful scholarship applicant would receive $500 a year regardless of need and would be eligible for an additional amount up to $500 a year on the basis of demonstrated need. This was the provision of Representative Elliot's bill, HR 13247. In the second step, merit as the basis for award was eliminated when the provision for scholarships was given up, and federal aid, through the states, to individuals was to be made available on the grounds of need through the loan fund. Associated with this provision was the understanding that applicants would be fully qualified on a minimal merit basis. The dominance of the need school of thought over the merit or honor school can be seen in another way in the absence in the final form of the bill of language dealing with "intellectual preeminence," "outstanding scholastic achievement," and honorary citations.

Trend of Action

Viewed generally, and over the period of time since last January, the trend of legislative action has been away from an active federal policy, by which the Government, through the states, seeks out, commends, and awards young people who have demonstrated superior intellectual ability, and toward a more passive policy by which the Government simply makes available the machinery and the funds for those students who are qualified and who do need financial aid. Rather than the Government going to the student, the student, under the compromise bill, *may* go to the Government.

East-West Nuclear Suspension

An East-West scientific conference on the suspension of nuclear tests that has been taking place in Geneva for 7 weeks closed on 21 August with the announcement that a "technically feasible" system for policing a world-wide nuclear test ban had been worked out. The participants in the discussions were scientists from the United States, Canada, Great Britain, France, the U.S.S.R., Poland, Czechoslovakia, and Romania. The group completed a 40-page confidential report, giving details of the recommended control system, that has been forwarded to the respective governments and will be made public later. Meanwhile, the conference members released a communique that said in part:

"In the course of the work of the conference, there was an exchange of opinions on the question of the various methods of detecting nuclear explosions.

"The conference came to the conclusion that the methods of detecting nuclear explosions available at the present time, viz. the method of collecting samples of radioactive debris, the method of recording seismic, acoustic and hydroacoustic waves, and the radio signal method, together with the use of on-site inspection of unidentified events which might be suspected of being nuclear explosions, make it possible, within certain specific limits, to detect and identify nuclear explosions, and it recommends the use of these methods in a control system.

"The conference noted that the combined use of the various methods considerably facilitates detection and identification of nuclear explosions.

"The conference of experts noted that the effectiveness of the methods considered will increase in course of time with improvement of measuring techniques and with study of the characteristics of natural phenomena which cause interference when explosions are detected.

"The conference has adopted an agreed conclusion regarding the technical equipment of the control system necessary for the detection and identification of nuclear explosions.

"The conference of experts reached the conclusion that it is technically feasible to set up, with certain capabilities and limitations, a workable and effective control system for the detection of violations of a possible agreement on the world-wide cessation of nuclear weapons tests.

"It was established in this connection that a network of control posts which were equipped with all the necessary apparatus appropriate to the various methods of detection of nuclear explosions should be disposed on continents and on islands, as well as on a few ships in oceans.

"The experts came to the conclusions that the control system should be under the direction of an international control organ which would ensure the coordination of the activities of the control system and the functioning of the system in such a way that it would satisfy the necessary technical requirements.

"On the 21st of August, 1958, the conference of experts adopted a final report for consideration by Governments. The report will be made public at a time to be determined by Governments."

The leader of the Western participants was United States delegate James B. Fisk, a member of President Eisenhower's Scientific Advisory Committee. In a closing statement he said:

"We on the Western side are gratified that the task set for this conference . . . has been successfully accomplished. . . .

"As scientists we have sought here to establish the facts pertinent to our subject, and to draw from them sound and logical conclusions regarding a system of control. . . .

"I speak for all of those on the Western side when I express our satisfaction at the friendly and cooperative working relationships which we have enjoyed with our colleagues on the other side of the table. . . ."

Evgeny Fyodorov, a leader in the U.S.S.R. satellite program, was spokesman for the Communist countries. His final remarks included the following:

"What is the basic conclusion which can be drawn following the completion of our lengthy task? The conclusion is very simple and very clear.

"A nuclear explosion, including an explosion of small magnitude, can be detected, and the establishment of an effective control system which would make it possible to have an inspection and a checking of the maintenance of an agreement on the universal cessation of nuclear weapons tests is a quite feasible undertaking and one which would not be particularly complicated.

"In certain instances the task of detecting and identifying nuclear explosions of small yields is relatively simple; in others, specific difficulties are involved.

"However, no matter where a possible violator attempted to conceal his atomic explosion–under the water, on the earth or in the cosmic space—100,000 kilometers [62,500 miles] from the earth —he will nowhere be guaranteed from exposure.

"The means by which these problems are to be resolved is indicated in our proposals which we have adopted. As technical experts, we have not discussed factors of a moral or social character."

A New Oreopithecus Skeleton

On the morning of 2 August 1958 a presumably complete skeleton of what is apparently an *Oreopithecus* bambolii, was discovered by a coal-miner at Baccinello, Italy, some 200 meters below the surface. All previous *Oreopithecus* specimens have been fragmentary. This discovery therefore is particularly noteworthy, since it may provide the evidence needed to settle definitely the controversy about the taxonomic position of *Oreopithecus,* a matter of prime importance [see *Science* **126**, 345 (23 August 1957)].

The block of lignite containing the skeleton will eventually be studied at the Natural History Museum, Basel, Switzerland, by Johannes Hürzeler, who, supported by the Wenner-Gren Foundation for Anthropological Research of New York City and some Swiss friends, has collected many specimens of *Oreopithecus* at Baccinello. Hürzeler was in Baccinello at the time of this latest discovery and personally supervised the difficult removal of the fossil from the mine. Incidentally, I write this from Basel, where I am studying *Oreopithecus* fossils through the generosity of the Wenner-Gren Foundation for Anthropological Research. It so happens that I visited the mine at Baccinello in company with Dr. Hürzeler the day before this new skeleton was found.

William L. Straus, Jr.
Naturhistorisches Museum,
Basel, Switzerland

Russian Journals Available in English

The National Science Foundation has just released a compilation of translations that indicates that approximately 60,000 pages a year of key Soviet scientific and technical journals are now available in English to United States scientists and engineers. The compilation shows that there are now in print 53 English editions of Russian journals, four extensive series of translated Russian abstracts, and four series of partial translations of important Russian journals. Support for the translations is provided by the National Science Foundation, the National Institutes of Health, the Office of Naval Research, and the Atomic Energy Commission (the latter two working through the National Science Foundation), and by six commercial translating and publishing firms working without government funds.

The National Science Foundation has maintained a foreign science information program since early 1952; its first Russian-to-English translation program was initiated in June of that year. The number of translated journals supported by the foundation has now reached 31, with most of the major fields of science being served.

Foundation-supported translation projects, continually increasing in number, are conducted by United States professional scientific societies and university groups which have chosen the Russian material to be translated and which have requested the financial support of the foundation. These organizations administer their own projects and provide expert consultation to translators to help insure accuracy. The translations are sold on a subscription basis, with the resulting income used to defray part of the costs of the projects, thus reducing the need for government support. The new NSF compilation gives a complete list of translated journals; information on the source of financial support, if any; the names and addresses of publishers; and annual subscription prices.

Education Research

The Office of Education, Department of Health, Education and Welfare, has released a report of the 78 projects started during the first year of its Cooperative Research Program, begun in July 1956, under a Congressional appropriation of $1,020,190. Most of the projects the first year were for research on education of the mentally retarded, since two thirds of the original appropriation was designated for that purpose. The remaining projects concerned identifying and developing unusual talent, educational aspects of juvenile delinquency, staffing schools and colleges, and other educational problems.

Research proposals submitted by colleges, universities, and state departments of education are reviewed by the Office of Education Research Advisory Committee. Seventy-two of the 78 first-year projects were undertaken by 30 colleges and universities, and the other six by state departments of education.

The Office of Education report was prepared by Romaine P. Mackie, Harold M. Williams, and Alice Y. Scates. Copies may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., at 25 cents.

Biophysical Science

A 4-week Study Program in Biophysical Science, the first of its kind, was held recently at the University of Colorado in Boulder under the sponsorship of the Biophysics and Biophysical Chemistry Study Section of the National Institutes of Health. Richard H. Bolt of Massachusetts Institute of Technology served as the program's executive director. It is expected that advances in the field will be accelerated through the exchange and critical evaluation of ideas and recent information.

More than 100 scientists from about 50 research organizations attended the study program. About 70 of these researchers presented lectures or presided as workshop chairmen. The lectures will be published in book form early in 1959.

Portable Nuclear Power Plant

The Argonne Low Power Reactor (ALPR), the prototype of a nuclear reactor designed to produce electric power and space heat at remote military stations, achieved criticality on 11 August at the Atomic Energy Commission's National Reactor Testing Station, Idaho Falls, Idaho. The ALPR-type plant is a "package" plant designed to be erected on any type of terrain and with a minimum of on-site construction. It contains a direct-cycle, natural-circulation boiling-water reactor fueled with enriched uranium and moderated with light water. The heat from the reactor can be used to generate 260 kilowatts of electricity and 400 kilowatts of space heat. The reactor is designed to operate for 3 years with each fuel loading.

Foreign Geologists to Receive Photogeologic Training

Training in the latest techniques of photogeology is being given by the U.S. Geological Survey in Washington to young geologists from abroad. The first group of four geologists from Chile, Ghana, and the Philippines has arrived. Although the 7-month training program is being given by staff members of the Geological Survey, it is sponsored by the State Department. Three additional groups of six participants each will begin training periods on 1 October 1958, 1 January 1959, and 1 April 1959.

Primary emphasis will be placed on geologic interpretation of air photographs. The techniques taught will be applied to the preparation of geologic maps of specific areas and regions. Participants are encouraged to bring a geological mapping program from their own country so that they may work on an area of high personal or national interest. In addition to instruction in photogeology during the course, participants will receive orientation in many other phases of geologic investigations as normally carried out by the Geological Survey.

Grants, Fellowships and Awards

Cerebral Palsy. The United Cerebral Palsy Research and Educational Foundation has expanded its program to include additional support of research and professional training. At the same time the foundation's concept of research in the field of cerebral palsy has been broadened to include support of basic and clinical studies encompassing the entire spectrum of brain damage and the consequences thereof.

The following new training programs are to be supported by the foundation: a postdoctoral fellowship program in brain research to support investigators-in-training in the broad field of research in the complex problem of neuromuscular disabilities; a clinical fellowship program to interest young physicians, in their residency years, in the problems of diagnosis, clinical management, and periodic follow-up of patients with neuromuscular disabilities; and a medical-student fellowship program to interest medical students in diagnosis, therapy, rehabilitation, and follow-up of patients with cerebral palsy and/or in participating in some phase of basic or applied research relating to the problems of brain damage.

The deadline for filing applications for grants and fellowships commencing 1 January 1959 is *15 September 1958*; for funds to become available 1 July 1959, the deadline for filing application is *15 March 1959*. For information write to: Director of Research, United Cerebral Palsy Research and Educational Foundation, 321 W. 44 St., New York 36, N.Y.

Gerontology. The Ciba Foundation, wishing to encourage research relevant to basic problems of aging, invites papers descriptive of work in the field for the fifth and final annual awards for 1959. Applications, which must be submitted by *10 January 1959*, may be obtained from G. E. W. Wolstenholme, Director, Ciba Foundation, 41 Portland Pl., London, W.1, England.

Not less than five awards, of an average value of £300 each, are available for 1959. Entries will be judged by an international panel of scientists that includes: C. H. Best, E. Braun-Menendez, E J. Conway, G. W. Corner, A. Haddow, V. R. Khanolkar, R. Nicolaysen, A. S. Parkes, F. Verzár, and F. G. Young.

Preference will be given to younger workers. The papers may be in the candidate's own language and should not be more than 7000 words in length.

Miniaturization. Nominations for the Miniaturization Award competition for 1958 are now being accepted. The award was established in 1957 by Miniature Precision Bearings, Inc., to recognize outstanding contributions by an individual or firm to the concept of miniaturization. It is administered by an independent committee of miniaturization experts representing industry, government, and education.

Participants in the competition may be individuals, companies or organizations which have broadened the horizons of miniaturization by creating a better understanding and use of the concept through education, research, engineering, or standardization. Entries should be submitted to the Awards Committee, Box 604, Precision Park, Keene, N.H.

News Briefs

An Indo-German agreement on the establishment at Madras of an Indian Institute of Technology for the training of Indian technicians was signed on 7 August in Bonn. According to the agreement, the Federal Republic of Germany will provide teachers, equipment for laboratories and work shops, and a library for the institute, while the Indian Government will provide the ground, the buildings and part of the personnel. Eventually, the institute will give India 250 trained technicians every 6 months.

* * *

The Metropolitan Life Insurance Company reports that a study of its industrial policyholders shows that in the last 15 years the death rate from cancer has decreased 15 percent for females and increased 8 percent for males. The report is based on a comparison of the cancer death rates among white industrial policyholders in 1936–1940 and 1951–1955.

* * *

The Southeastern Forest Experiment Station, Asheville, N.C., has announced that a forest-fire research laboratory, first of its kind in the country, is being built near Macon, Ga., and is scheduled to begin operating early in 1959. The laboratory is a joint undertaking of the U.S. Forest Service and the state of Georgia.

* * *

The U.S. Census Bureau has reported that American women of child-bearing age, 15–44, gave birth to an average of 22 percent more children in 1957 than in 1950. The increase was greatest in the city areas, among nonwhites, and in low- and middle-income groups. Over-all birth rates remained higher in farm areas than in cities. About 75 percent of the wives 35 to 39 years old in 1957 had already borne two or more children; 46 percent had borne three or more and about 14 percent had borne five or more.

* * *

The Ramo–Wooldridge Corporation and General James H. Doolittle have jointly announced that, effective 1 January, Doolittle will become chairman of the board of directors of the Space Technology Laboratories. Previously a division of Ramo-Wooldridge, the laboratories will become a separate corporation with an independent board of directors. Space Technology Laboratories has over-all scientific responsibility for the Air Force's Thor, Atlas, Titan, and Minuteman missile programs, and also is engaged in a broad experimental program on advanced space technology.

* * *

The U.S. Civil Service Commission is seeking bacteriologists, serologists, biochemists, biologists, and physicists (in the field of radioisotopes) for duty with the Veterans Administration in hospitals and regional offices throughout the United States and its territories and possessions. No written test is required. Applications must be filed with the Executive Secretary, Central Board of U.S. Civil Service Examiners, Veterans Administration, Washington 25, D.C.

* * *

As the result of deep-water soundings recently completed in Lake Superior by the U.S. Army Corps of Engineers, future charts will show a new maximum depth of 1333 feet. This sounding is located in United States waters off the Marquette–Munising region of Michigan. The greatest known previous depth was in Canadian waters near Caribou Island.

Scientists in the News

BERTHA S. ADKINS of Salisbury, Md., for 8 years assistant chairman of the Republican National Committee, has been sworn in as Under Secretary of the Department of Health, Education, and Welfare.

S. M. DIETZ of Oregon State College has retired as chairman of the department of botany, head of botany and plant pathology in the Experiment Station, and administrator of the herbarium. He will continue teaching and research as research professor in plant pathology. Dietz is succeeded by ROY A. YOUNG, who for the past 10 years has taught graduate courses in plant pathology and conducted research on diseases of ornamental plants.

MARGARET E. PATTERSON resigned on 15 July from Science Service of Washington, D.C., where she had been executive secretary of Science Clubs of America for 17 years. Miss Patterson left science teaching to start science clubs on a nationwide basis. Now SCA has more than 20,500 members in this country and abroad.

In 1942 she helped to design and establish the Science Talent Search for

the Westinghouse Science Scholarships and Awards and has been responsible for the conduct of this competition since that time. In 1950 she aided in the creation of the National Science Fair and has been active in its development.

The July number of the *Journal of Investigative Dermatology* is an issue honoring STEPHEN ROTHMAN, professor of dermatology at the University of Chicago and author of *Physiology and Biochemistry of the Skin*. The issue consists of contributions by men who have been students or associates of Rothman. It also contains a detailed biography and bibliography of Rothman, who has pioneered in modern investigative dermatology.

ELI LILLY, chairman of the board of directors of Eli Lilly and Company, Indianapolis, Ind., has been named recipient of the Remington Honor Medal of the New York Branch of the American Pharmaceutical Association. This medal will be presented at the Remington dinner which will be held on 10 December at the Hotel Roosevelt in New York.

I. S. RAVDIN, John Rhea Barton professor of surgery at the University of Pennsylvania and chairman of the department of surgery, has been appointed the university's vice president for medical development. Ravdin's appointment follows the recently announced resignation of NORMAN H. TOPPING, who was elected president of the University of Southern California after having served as vice president for medical affairs at Pennsylvania since 1952.

JOHN M. MITCHELL, dean of the Pennsylvania School of Medicine, has been given the additional title of vice provost of the university. He will be responsible for the development work previously carried on by Topping.

MICHAEL E. DEBAKEY, professor of surgery at Baylor University School of Medicine, has received the Alvarenga Prize of the College of Physicians of Philadelphia for his outstanding work in the surgical treatment of diseases of blood vessels. The Alvarenga Prize, an annual award, was established by the will of Pedro Francisco DaCosta Alvarenga of Lisbon, Portugal, an associate fellow of the College of Physicians of Philadelphia who died on 14 July 1883.

ROGER B. FRIEND, formerly chief entomologist and vice-director of the Connecticut Agricultural Experiment Station, New Haven, has retired after 34 years on the station's staff. Following 3 years as a graduate assistant, he was made assistant entomologist in 1927 on completion of requirements for the Ph.D. at Yale University. Pests imported from abroad were his first interest, especially insects attacking forest and shade trees, and he made comprehensive studies of their biology and control. He has conducted research on the imported birch leaf miner, the European pine shoot moth, and the gypsy moth. Friend was appointed chief entomologist in 1939; a year later he was made vice-director, a post he filled until December 1951. He expects to continue his research as an emeritus member of the staff.

ANTHONY W. SMITH, well-known conservationist, has been named executive secretary of the National Parks Association, Washington, D.C. He has been a member of the board of trustees and the executive committee of the association for many years. He is also a member of the executive committee of the Citizens Committee on Natural Resources.

Consolidated Electrodynamics Corporation, Pasadena, Calif., has announced the appointment of CHARLES F. ROBINSON as chief research physicist and LELAND G. COLE as chief research chemist. Robinson joined the corporation in 1947 as a staff physicist and became senior physicist in 1952. Cole joined in 1955 as senior chemist.

TROY L. PEWE, past president of the AAAS Alaska Division, has been named first head of the department of geology at the University of Alaska, College, Alaska. Péwé has been serving as geologist-in-charge for the U.S. Geological Survey's Alaskan Geology Branch at College, a post he will continue to fill during the summer months.

President Eisenhower has accepted the resignation of EDWARD TELLER as a member of the general advisory committee to the Atomic Energy Commission. Teller resigned because he felt that his job as director of the University of California Radiation Laboratory at Livermore conflicted with membership on the advisory committee. The laboratory is under the AEC and Teller has been its director since 1 April.

RAYMUND L. ZWEMER has joined the staff of the science adviser in the Department of State. He has most recently been with UNESCO in Paris, for 2 years as chief of the Division of International Cooperation for Scientific Research, and the last 6 months as chief of the Bureau of Personnel and Management. His particular responsibility in the Office of the Science Adviser will be with the science programs of intergovernmental organizations, both international and regional.

Recent Deaths

GORDON E. DEAN, Nantucket, Mass.; 52; senior vice president in charge of nuclear energy for General Dynamics Corporation and chairman of the board for the Nuclear Science and Engineering Corporation; chairman of the Atomic Energy Commission from 1950 to 1953; 15 Aug.

WILLIAM W. HINCKLEY, New York, N.Y.; 48; psychologist with the Bleuler Psychotherapy Group, Jamaica, N.Y.; 15 Aug.

ALBERT G. INGALLS, Cranford, N.J.; 70; assistant editor of *Scientific American*; author of three books on amateur telescope making; 13 Aug.

SAMUEL IVES, Madison, Wis.; curator of rare books at the University of Wisconsin; had started a bibliography of early chemical and medical books at the time of his death; 9 Aug.

CHEVALIER JACKSON, Philadelphia, Pa.; 92; noted for perfecting the technique for using the bronchoscope; had been professor of laryngology at the University of Pittsburgh, Jefferson Medical College, and the University of Pennsylvania Graduate School of Medicine; founder of the Jackson Bronchoscopic Clinic at Temple University; 16 Aug.

FREDERICK JOLIOT–CURIE, Paris, France; 58; nuclear physicist and French High Commissioner for Atomic Energy from 1946 to 1950; shared the Nobel Prize in chemistry with his late wife Irene for producing artificial radioactive elements for the first time; 14 Aug.

KARL S. LASHLEY, Jacksonville, Fla.; 68; director of the Yerkes Laboratories, a division of Emory University, from 1942 until his retirement in 1955; formerly professor of neuropsychology at Harvard University and professor of psychology at the University of Minnesota and the University of Chicago; psychologist at the Institute for Juvenile Research in Chicago; 7 Aug.

JOHN H. MARSHALL, Guildford, England; 82; noted archeologist and explorer; director general of archeology in India from 1902 to 1931; discoverer of buried cities on the Indus River that are more than 5000 years old; 18 Aug.

GEORGE B. PEGRAM, Swarthmore, Pa.; 81; vice president emeritus of Columbia University; directed a research group at Columbia University that led to the development of the atom bomb; contributed individually to the development of atomic science; 12 Aug.

VICTOR ROSS, South Yarmouth, Mass.; 64; research associate in biochemistry at the College of Physicians and Surgeons at Columbia University from 1939 to 1954; member of the staff of the chemistry department of Montefiore Hospital; 9 Aug.

Book Reviews

Space, Time, and Creation. Philosophical aspects of scientific cosmology. Milton K. Munitz. Free Press, Glencoe, Illinois, and Falcon's Wing Press, 1957. x + 182 pp. $3.75.

For anyone interested in modern operational thinking, the reading of Munitz' crystal-clear exposition of the aims and possibilities of our scientific methods is a real pleasure. The book offers precisely what one would expect from a philosopher—a discussion of wider perspectives than those an observational astronomer can afford to spend much time on. It reminds one of Reichenbach's *The Rise of Scientific Philosophy* in its disavowal of absolute thinking in favor of true—that is, relational—thinking. The keynote of the present book is stated immediately: "The task of logic or critical philosophy is not to understand the universe, but to understand in what such understanding consists." This theme is preserved throughout the book and gives it great unity. It is reminiscent of Reichenbach's contention that, while we cannot hope to find absolute truth, we can perhaps expect to understand why it is that we wish to know it.

The language and style of Munitz' volume is exceedingly precise, without any touch of the pedantry one usually fears to find in opening a philosophical essay. Although the author gives us remarkably clear bird's-eye views of the four or five principal cosmological models, he has us consider, not so much questions like "Is the universe finite?" or "Is there creation of matter?" but, rather, what is the legitimate meaning of these questions—what, for instance, do we really mean by the term *universe*? And what precise meaning can we attach to the term *creation of matter*?

The first four chapters outline some of the cosmogonies, from the Marduk myth to Hoyle's version of the steady-state universe. The discussion illustrates and critically examines the nature of scientific statements in general. We are gradually led to realize that any theory worthy of the name contains rules for making inferences whereby one can prescribe the general type of process by which predictions can be made from known facts to indicate probabilities of finding further facts. Whatever unifying scheme or symbolic representations may be adopted as tools, the most essential fact of any theory is always a rule of induction to predict further facts from a limited body of known facts. The value of a theory is measured by its degree of comprehensiveness, its predictive power, and its economy of conceptual means—what Einstein called its simplicity. It is particularly to be noted that one cannot talk about a part of a theory being true, the rest false. The truth of a theory is measured by the agreement of its predictions with observed facts. If this argument fails, the truth of the whole theory, not merely of a last inference from it, is questioned.

With this background we are then asked to consider the meaning of the term *universe*. In cosmology a universe is nothing but "an expression for the system of connections, facts, and usages which refined and tested thought has come to accept in one domain of experience. It means nothing apart from this funded background." To illustrate: there is the Universe of the cosmologist, the Universe of Life for the biologist, the Universe of Mind for the psychologist, the Universe of Spirit for the theologian, and the Universe of Matter for the physicist. None of these "universes" is an "object" in any other sense than that of a connected body of facts and deductions. We must give up the naive viewpoint that there is an entity called "the Universe-as-it-exists-in-itself," which would exist out of mind, independently of whether we observe its facts or not. There are only the physical and relational facts or observations and the rule of inference for obtaining more facts, partly physical, partly mental. A cognitively inaccessible *Ding-an-sich*, the layman's matter-of-fact view of the world, is a metaphysical monstrosity, wholly divorced from any meaning amenable to scientific discourse and inquiry. As de Sitter has remarked in one of his lectures, "the universe is a theory just as much as the atom." The same is the case with "the gene," or "the atom of life," or "the nature of God," or "the macroscopic atom of concretion."

While there are many spectacular popular expositions of today's specific cosmological models, only those written by philosophers begin to show to what degree the modern world pictures are mental fictions. The last six chapters of the present book constitute such an account. Rather than dwell upon dimensions and figures, the author lays bare the logic of the constructions in sufficient detail to pursue a critical examination and a well-grounded criticism of the whole scheme. It is shown that in some cases theory goes so deep as to prescribe what shall be the type of fact considered as a physical law of nature. Under the heading "Rationalism," the conventional expanding-universe theories are all shown to contain, first, observational premises; second, a physical theory verified in our immediate spatial neighborhood; and third, a rule of extrapolation to greater distances and perhaps wider classes of observational data. No presumption is made that such a theory is certain, complete, or unique. E. A. Milne's view, however, is diametrically opposite. He cares nothing for the "irrational" laws of microscopic, or even gravitational, physics. It is better, he maintains, to establish a cosmological scheme right out of our heads on a wholly deductive basis as a self-sufficient discipline and then see how much of the known physics can be fitted into the scheme. But even if nothing fits of the small-sale ordinary physics, one should not tamper with "the great intuitional simplicities" which are the basis for his world view. According to Munitz this is not scientific at all. The fallacy lies in thinking that there are available rival "deductive" and "inductive" methods in science. One cannot help recalling the same criticism voiced forcefully by F. J. M. Stratton (in 1953, in *The Observatory*), who considers Milne's methods "pre-Copernican" in their special appeal to esthetics through his "cosmological principle."

The little volume by Milne entitled *Modern Cosmology and the Christian Idea of God* also comes in for some fair criticism. The statements "the universe is unique" and "the world was created at a definite point in time on the scale of observers in relative uniform motion" are analyzed as to their precise meaning. There are only two cases to consider: "the observable universe," which is the same for all theories, and "the universe," which is defined by the rules of an adopted theory and is, therefore, as much a unique physicomental reality on the basis of any other theory as it is on that of Milne's "kinematic relativity" view. As to the sense of Milne's creation epoch, this was already latent in his introduction of the "cosmological principle": "The world views of any two

equivalent observers (observers moving with the substratum in their respective neighborhoods) are identical." One must read his 1934 articles in *Zeitschrift für Astrophysik* (in English) or his book *Cosmogony and World Structure* in order fully to realize how rich can be the crop of deductions reaped in a signaling universe, such as Milne's, from this innocent-looking principle.

An excellent discussion of the curvatures of space-time manifolds is given in the chapter on world geometry. Newton's extensional, Leibniz' relational, and Einstein's physical, views of space are well described. Robertson's simple formulas to show how different "curved" spaces differ from "flat" space are quoted. It appears that the unfortunate term *curvature* has nothing whatever to do with change of direction. A much better term would have been *distance-deficit,* or *distance-excess* of perimeter, area, or volume, as the case may be. The fact is stressed that all kinds of spaces are capable of serving as world maps, with proper laws adopted for the phenomena described, but that only certain kinds of space are convenient mathematically.

A chapter on "The Age of the Universe" follows, in which it is shown that the current estimates for the expanding universe, whether on the old or the new time scale, are very far from being in any sense factual. While it is true that the Hubble constant enters into the computation of the "age," McVittie has stressed that a factor depending upon the model, a pure guess that the present radius of curvature is about 100 times the original Einstein radius, and an assumption of the average density of matter in the observed universe (an estimate which is still uncertain within a factor of 1000 according to some observational astronomers) all enter into the computation of the age. In addition to these uncertainties, we do not know that the nebulae have always moved at their present constant speeds. Accelerations and decelerations with time are at present being considered as possibilities. The result is that we know nothing certain about the age of the universe. But why should we expect to find an age for it at all, since "the universe" is really a view point, like "the atom."

The last two chapters contain a discussion of the cosmology of the steady-state universe. The "perfect cosmological principle," introduced in Bondi's version of it, may be stated as follows: "Apart from local irregularities, the universe presents the same aspect from any place at any time." With this principle at work, the steady-state universe permits the continual creation of matter in space. The author does not say this is impossible, but he maintains that there is no real evidence for it, and that it would have been far more scientific to postulate a universe of constant density in time than to assert that the cause of this constant density is creation of matter. The "perfect cosmological principle" is, he thinks, no better than an Aristotelian argument from esthetic simplicity —that is, a post-Copernican anachronism. It is not a factual statement capable of serving as a premise in an argument but a definition that functions as a criterion of what is to be regarded as a law of nature.

Finally, we are asked to consider in what sense there is creation of matter in the universe. The meaning of the term *creation* is twofold, but neither sense of the word is acceptable as a cosmological postulate. The first—namely, the shaping of objects out of already existing material—requires an agent, a primordial material, and, usually, a purpose. It is irrelevant on the large scale of cosmogony and could at best enter for the first time on the scale of nebular astronomy. But it is the second meaning, "the appearance of physical matter in time and space out of nothing," which is generally attached to the word *creation,* used by itself. Hoyle's version of the steady-state universe is carefully analyzed. It is given credit for what it is— the first complete field theory of the process of creation—but perhaps not enough credit. In the discussion of this subject it is obvious that Munitz possesses a precise knowledge both of Hoyle's technical paper of 1948 and of his popular writings. Since the appearance of the latter, in 1950, the theory of the creation *ex nihilo* of matter in three-dimensional space has caused great furor among the general reading public, due, perhaps, to a too literal acceptance of a condensed popular statement in the volume entitled *The Nature of the Universe.* The statement is: "New material appears to compensate for the background material that is constantly being condensed into galaxies. . . . I find myself forced to assume that the nature of the Universe requires continuous creation—the perpetual bringing into being of new background material." While it is hazardous to judge a man's precise meaning on an ultimate subject from his radio lectures or other popular writings, there is no doubt that Hoyle thinks of a four-dimensional vector representation of a four-dimensional flow of energy. The vector has a nonzero component in the time direction, and this appears in three dimensions as an arrival of matter (a form of energy) with zero velocity at various points in space, out of nothing observable—that is, it appears as creation out of nothing in three dimensions.

McCrea of London is given the credit for having elaborated the process to show that it is not a creation of new energy *ex nihilo* in four dimensions but the conversion of a negative four-dimensional stress into energy. But it appears to me that the germ of this idea is present also in Hoyle's 1948 paper. This appears from his two equations describing the process of creation. He also states, in his book *Frontiers of Astronomy,* that the creation of matter contemplated is due to the matter at infinity—that is, matter beyond our relativistic horizon. In other words, to Hoyle, the "creation of matter" appears *ex nihilo* only in three-dimensional space. It is but an aspect of four-dimensional conversion of energy already existing in some form in four-dimensional space-time. It is therefore, at bottom, a conversion of something existing in four dimensions only, so that it exists on paper only! This being clearly a consequence of the postulates adopted at the very beginning of Hoyle's treatment of relativity, the attentive reader would never have the occasion to doubt that when Hoyle uses the term *creation* he means "creation into our three-dimensional physical experience," not "creation out of nothing." Hence, the furor should not have been permitted to flourish long. Once this is clear, one can perhaps pardon an Englishman for not adding, over and again, "into our three-dimensional physical experience" every time the idea of creation is referred to. However, this is a serious matter to the philosopher and is severely criticized by the present author. The criticism goes deeper than the mere use of words. It touches upon the meaning of physical reality. Although not specifically stated, it appears that the author does not consider the fourth, timelike dimension of space-time a physical experimental reality—a view that certainly needs to be stressed in our own age, which permits four-dimensional universes to be talked of as if they had the physical status of basketballs. It is not the physical motion of a particle that is four-dimensional, it is the history of the motion. It is not the physical universe that is four-dimensional, it is our formal mental representation of it that is. We never measure physically "the fourth dimension" any more than we directly measure "the universe" or "the atom."

The Dutch mathematician Struik points out in his little book on four-dimensional geometry that in our experience of nature there never are more than three physical dimensions. (By "physical" is, of course, meant measurable in principle by electromagnetic or gravitational fields.) It is therefore understandable that a philosopher takes exception to Hoyle's constant use of the term *creation* by itself. For with this abbreviated use one normally associates *ex nihilo,* an unnecessary and harmful scientific con-

cept. It dogmatically closes a subject, while the whole advantage of theory is to open up new possibilities of finding facts—physically measurable quantities —never to expostulate a supernatural entity. Infinity or finitude of a universe may be equally useful—nay, equally true—concepts as rules of extrapolation to new measurable facts. It is the set of rules, blended with physical theory, represented by mathematics (multidimensional or not), used as an extrapolation tool, and not a metaphysical "thing-in-itself," which constitutes the "universe" of cosmology.

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Handbuch der Physik. vol. 50, *Astrophysics,* I. S. Flügge, Ed. Springer, Berlin, 1958. vii + 458 pp. Illus. DM. 98.

It was an excellent idea on the part of the editor of the new *Handbuch* to include volumes on such borderline fields as geophysics and astrophysics. Indeed, a good astrophysicist is a much more complete physicist nowadays than most of his much-too-much-specialized physicist colleagues. An astrophysicist has to know quantum mechanics and electromagnetic theory to understand stellar spectra; nuclear physics to understand the energy production in stars; diffusion theory, thermodynamics, and statistical mechanics to understand the equilibrium in stellar atmospheres; ordinary and magnetohydrodynamics to understand many of the processes in interstellar space; Hamiltonian mechanics to understand celestial mechanics; and so on. Part of this many-sidedness of modern astrophysics can be gleaned from the first astrophysics volume of the new *Handbuch.* One can also see the truly international character of the subject from the fact that, of the ten contributions from four different countries, two are in German, three are in French, and five are in English.

It is clearly impossible in the restricted confines of a review to do justice to a volume such as the present one, and one must limit oneself to a brief summary of the contents of the various contributions. The emphasis in this volume has been predominantly observational, although the longest paper deals with the theory of stellar atmospheres.

The first contribution is by Fehrenbach (Marseilles), who gives a comprehensive survey of spectral classification of stars, comparing the different possible classifications. Keenan (Delaware, Ohio) discusses briefly metallic line stars, F-, G-, and K-type high-velocity stars, and stars with carbon features, while Swings (Liège) gives a survey of molecular bands in stellar spectra. Wurm (Hamburg) contributes two papers, the first one dealing with the observational data and the second one, with the theoretical interpretation of the spectra of planetary nebulae. Greenstein (Pasadena, Calif.) discusses white dwarfs, and van de Kamp (Swarthmore, Pa.), visual binaries. Gaposchkin (Cambridge, Mass.) deals with eclipsing, and Struve and Huang (Berkeley, Calif.), with spectroscopic binaries. The last contribution includes a discussion of several peculiar systems and of the evolution and origin of binaries. Finally, Barbier (Paris) treats the theory of stellar atmospheres in ample detail.

As one has come to expect from the *Handbuch,* the standard is high throughout, and the publishers have produced a book which is a pleasure to handle. As a consequence of its subject matter, it contains a large number of half-tones, well reproduced.

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Shell Theory of the Nucleus. Eugene Feenberg. Princeton University Press, Princeton, 1955. xi + 211 pp. $4.

The shell theory of the nucleus in its initial stages of development was rejected because of the apparent conflict with the strong, short-range character of nuclear forces. It is now a challenge to the more fundamental approaches to nuclear structure to explain the shell model's unexpected success. Feenberg, a leader in the development of shell model ideas, has written a valuable description of the model's interpretation of low-energy nuclear phenomena.

The book begins with a brief historical introduction describing the experimental information that led early workers to hypothesize the shell structure of nuclei. A quantitative presentation of the independent particle approach is then given and used in the following chapters to interpret a variety of nuclear phenomena in terms of the shell model. Magnetic dipole and electric quadrupole moments are treated. Shell model predictions of the character and location of isomeric transitions are correlated with experimental data. The classification of beta decay according to shell model states is given, along with an analysis of favored beta decay. Of particular value is the analysis of j-j coupled configurations in which the isobaric spin formalism is used. Several beta decay matrix elements and magnetic moments are calculated explicitly as examples. One chapter is devoted to collective motion and its connection with shell structure. The final chapter is an introduction to what Feenberg terms the third stage of development—namely, the attempt to relate our knowledge of the nucleon-nucleon force to the problems of nuclear structure.

In total, the book provides a remarkably fine introduction to the shell model approach and has already proved very useful to students of nuclear physics.

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Textile Chemicals and Auxiliaries. With special reference to surfacants and finishes. Henry C. Speel and E. W. K. Schwarz. Reinhold, New York; Chapman & Hall, London, ed. 2, 1957. vi + 545 pp. $13.50.

This second edition differs from the first edition published in 1952 in containing market data on textile chemicals and a chapter on "Felts and non-woven fabrics." It also contains information on newer developments in flameproofing and other types of finishing, new trademarked products, and new fibers, but the total amount of new material is small.

Although the type is clear, numerous obvious errors detract from the book. These include errors in chemical formulas and spelling, replacement of words with words of somewhat similar appearance but different meaning, and scrambled sentences and paragraphs.

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Advances in Cancer Research. vol. V. Jesse P. Greenstein and Alexander Haddow, Eds. Academic Press, New York, 1958. ix + 463 pp. Illus. $10.80.

The fifth volume of this series maintains the high standard for informative, scholarly reviews set by the preceding four volumes. The *Advances* is now a standard reference, and any cancer research laboratory or clinic is quite incomplete without it.

The first chapter, on "Tumor-host relationships," by R. W. Begg, sets the main theme of the volume. There is certainly no doubt that neoplasms produce biochemical and morphological changes in tissues distant to, and free of, the tumor, but exploitation of these effects except in a few small specific instances still remains for the future. Three additional chapters deal with aspects that may be related to this topic. "Anemia

in cancer," reviewed by V. E. Price and R. E. Greenfield, as one of the complex end results of the neoplastic process, may well be related to the "Specific tumor antigens" which L. A. Zilber describes, as an autoimmunization effect, or to the catalase-reducing, heat-stable proteose with which W. Nakahara and F. Fukuoka deal in their "Newer concept of cancer toxin."

P. N. Campbell describes "Protein synthesis with special reference to growth processes both normal and abnormal." The Weisburgers give a full account of the "Chemistry, carcinogenesis and metabolism of 2-fluorenamine and related compounds"; these intriguing chemical "polycarcinogens," unlike the aromatic hydrocarbons, fortunately seem to maintain the fruitful interest of biochemists. P. R. Peacock presents a timely chapter on "Chemically induced tumors of fowls." The role of viruses is not any clearer in these neoplasms than in other species, despite the present popularity of this concept.

C. Berman condenses his long-term interest in "Primary carcinoma of the liver" into a short, clinically oriented chapter. Despite the fact that only relative frequency figures are available as an index of its occurrence, it is clear that liver cancer is an environmental neoplasm of epidemic proportions in South Africa, India, and the Far East. It is one of the neoplastic afflictions of mankind (along with carcinoma of the bladder associated with infestation by *Schistosoma haematobium,* and epidermoid carcinoma of the lung induced by cigarette smoke and other air pollutants) in which research and public health can join hands in an international effort, with the victory of substantial prevention being an assured, achievable goal.

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Land of the Tollund Man. The prehistory and archaeology of Denmark. Palle Lauring. Translated by Reginald Spink. Macmillan, New York, 1958. 160 pp. Illus. $6.

If it is not correct to call the *Land of the Tollund Man* a book for professional archeologists, neither is it fair to call it merely a popular book on the archeology of Denmark. A judiciously limited amount of straight archeological fact is clothed in cultural dress based on stimulating data from other fields and trimmed with theories and speculations which are always carefully distinguished from the facts.

In the first chapter, Lauring's description of the changes in land and climate, based on the latest views of glacial geology and geography, clarify the limited picture of man's first appearance in Denmark. As the archeological story progresses, the chapters abound with a variety of subjects: modern experimentation in flint-flaking, including rather bloody attempts by the author himself; religious ideas that may have underlain the practice of constructing megalithic monuments; a comparison of the economics of farming in Neolithic and modern times; accidentally preserved costumes of the Bronze Age; the necessity of postulating a powerful organization in Bronze Age Denmark which exported local products, largely amber, on a large scale and which demanded and made use of expensive bronze and gold objects in return; the construction of Iron Age boats; and the importance of the sea in Denmark's economy in all periods.

Among the most interesting finds are the treasures and well-preserved human bodies found in bogs. The condition of the body, with face bashed in, throat cut, or with a noose around the neck, gives Lauring the opportunity to recreate the scene of sacrifice in vivid, melodramatic prose. One of these sacrifices, the Tollund Man, supplies the title to the book.

The final chapter carries the story down through the Germanic Iron Age, in which the foundation for the Viking period was laid.

The book is illustrated with 77 photographs of exceptionally high artistic and technical quality.

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Communicable Diseases. A bibliography of internal medicine. Arthur L. Bloomfield. University of Chicago Press, Chicago, 1958. viii + 560 pp. $10.

In the preface Bloomfield states that "The surge of new knowledge in medicine has created a tremendous problem both for the student and for the practitioner . . . . In current medical writing what is referred to as the 'older literature' often turns out to be that of the previous decade . . . . In brief, there is a real danger that we shall become completely cut off from our medical past and relapse into a sort of modern Dark Age."

With this situation in mind, Bloomfield, professor emeritus of medicine at Stanford University School of Medicine, has compiled this bibliography of communicable diseases. Thirty diseases are included: typhoid fever, cholera, bacillary dysentery, plague, brucella infection, pneumococcal pneumonia, scarlet fever, erysipelas, rheumatic fever, meningococcal infection, gonorrhea and gonococcal infection, tuberculosis, leprosy, diphtheria, tetanus, typhus, syphilis, malaria, amebic dysentery, influenza, poliomyelitis, the common cold, measles, smallpox, vaccinia, rabies, yellow fever, herpes zoster, mumps, and whooping cough.

References cover the period from about 1800 to the present. An author index is included.

Bridges and Their Builders. David B. Steinman and Sara Ruth Watson. Dover, New York, rev. ed., 1957. xvi + 401 pp. Illus. Paper, $1.95.

The first book devoted solely to bridges did not appear until 1714, but this lack of specialized information has been fully remedied in more recent times. There is today a legion of technical publications available to the modern bridge engineer which would fill a major size library. These many works reveal the fascinating story of the bridgebuilder's ever-increasing competence and ingenuity in more effectively and economically meeting man's continually expanding needs for such basic transportation facilities. Unfortunately, however, this story is both largely unavailable to the layman and obscured by technical terms and details. As a result, the few popular books on bridges which have been issued are largely pictorial in character and seldom attempt to explain either the simpler problems of bridgebuilding or the many factors, from the availability of materials and the economics of construction to the compelling forces of need and cost, that condition the labors of the bridgebuilder. Such works thus offer little to enlighten the layman and little of value to the engineer.

The authors of this book, a revised and enlarged edition of a work first published in 1941, have attempted to follow a middle course. They have selected a group of notable bridges, especially more recent works, and have told the story of these bridges and of their builders with clarity and in some detail. Steinman is a well-known bridge engineer, and, while some of his interpretations of the reasons which led to the adoption of earlier bridge forms may be questioned, both the layman and the engineer will find much of interest in this effort to reveal "man's conception and creation of bridges."

As the authors note, engineering and architecture went hand in hand through earlier ages, and it was not until the 18th century that the design of bridges broke away from the overpowering artistic architectural interests of the Renaissance and a truly modern era of rationalized bridge design began to emerge. This movement was initiated in France, espe-

cially following the creation of the Corps des Ponts et Chaussées in 1716, but the forces prompting it became more insistent with the advent of iron in sufficient quantity and at a cost that made its use in bridges possible. This arrival of a real Iron Age, plus the advent of the railroad and, in the present century, motor transportation, have made it necessary for the engineer to continually create bigger and better bridges, many of which are interestingly described in *Bridges and Their Builders.*

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New Books

List of Films on Human Anatomy and Embryology. Association Néerlandaise du Cinéma Scientifique, Catharijnesingel 59, Ingang Sterrenbos, Utrech, Netherlands; Association Internationale du Cinéma Scientifique, 38, Avenue des Ternes, Paris 17e, ed. 2, 1957. 213 pp.

Reaktionsmechanismen. Volker Franzen. Huthig, Heidelberg, Germany, 1958. 160 pp. DM. 18.

Space Flight. Satellites, spaceships, space stations, and space travel explained. Carsbie C. Adams; Assisted by Frederick I. Ordway, III, Heyward E. Canney, Jr., Ronald C. Wakeford. McGraw-Hill, New York, 1958. 389 pp. $6.50.

Elektrochemische Sauerstoffmessungen. Konzentrationsmessungen oxydierender und reduzierender Stoffe durch galvanische modellelement. Fritz Todt. Gruyter, Berlin, 1958. 232 pp. DM. 36.

Resource Training for Business, Industry, Government. Including a report of the First Conference on Graduate Training in Resources, University of Michigan, April 1956. Published for the Natural Resources Study Committee by the Conservation Foundation, New York, 1958. 159 pp.

Industrial Hygiene and Toxicology. vol. 1,*General principles.* Frank A. Patty, Ed. Interscience, New York and London, ed. 2, 1958. 858 pp. $17.50.

Cosmic-Ray Results. From Huancayo, Peru, January 1946–December 1955, Instituto Geofísico de Huancayo; Cheltenham, Maryland, March 1936–December 1955; U.S. Coast and Geodetic Survey, Cheltenham Magnetic Observatory; Christchurch, New Zealand, January 1947–December 1955, Department of Scientific and Industrial Research, Magnetic Survey Division; Godhavn, Greenland, January 1947–December 1950; Det Danske Meteorologiske Institut, Geofysisk Observatorium. Researches of the Department of Terrestrial Magnetism, vol. XX. Isabelle Lange and S. E. Forbush. Carnegie Institution of Washington, Washington, D.C., 1957. 229 pp. Paper, $2; cloth, $2.25.

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Inspection for Disarmament. Seymour Melman, Ed. Columbia Univ. Press, New York, 1958. 291 pp. $6.

Principles of Internal Medicine. Edited by T. R. Harrison, Raymond D. Adams, Ivan L. Bennett, Jr., William H. Resnik, George W. Thorn, M. M. Wintrobe, Eds. Blakiston Div., McGraw-Hill, New York, ed. 3, 1958. 1860 pp. $18.50.

The Population of Japan. Irene B. Taeuber. Princeton Univ. Press, Princeton, N.J., 1958. 481 pp. $15.

The Science of High Explosives. Melvin A. Cook. Reinhold, New York; Chapman & Hall, London, 1958. 455 pp. $22.50.

Introduction to Nuclear Engineering. Richard Stephenson. McGraw-Hill, New York, ed. 2, 1958. 502 pp. $9.50.

Klinische Calorimetrie und Thermometrie. Die thermischen messverfahren zur registrierung der haut- und gewebedurchblutung am menschen. Grundlagen, technik, methodik, anwendung in klinik und praxis. Helmut P. Kuemmerle. Thieme, Stuttgart, Germany, 1958 (order from Intercontinental Medical Book, New York 16). 112 pp. $4.30.

The Neutrino. James S. Allen. Princeton Univ. Press, Princeton, N.J., 1958. 176 pp. $4.50.

Chemical Engineering Practice. vol. 4, *Fluid State.* Herbert W. Cremer, Ed. Academic Press, New York; Butterworths, London, 1957. 648 pp. $17.50.

Children of the Kibbutz. Melford E. Spiro. Harvard Univ. Press, Cambridge, 1958. 520 pp. $10.

Commercial Fruit and Vegetable Products. W. V. Cruess. McGraw-Hill, New York, ed. 4, 1958. 891 pp. $15.

Reprints

The Japanese Abacus. Its use and theory. Takashi Kojima. Tuttle, Rutland, Vt., 1958. 102 pp. Paper, $1.25.

The Typhoon-Hurricane Story. Robert E. Fuerst. Tuttle, Rutland Vt., 1958. Paper, $1.50.

Microwave Transmission Design Data. Theodore Moreno. Dover, New York, 1958. 257 pp. Paper, $1.50.

Mathematical Tables of Elementary and Some Higher Mathematical Functions. Herbert Bristol Dwight. Dover, New York, ed. 2, 1958. $1.75.

History of Mathematics. vol. I, *General Survey of the History of Elementary Mathematics;* vol. II, *Special Topics of Elementary Mathematics.* David Eugene Smith. Dover, New York, 1958. 618 pp.; 737 pp. Paper, $2.75 per volume; set, $5.

Functions of Real Variables. William Fogg Osgood. 407 pp. *Functions of Complex Variable.* William Fogg Osgood. 262 pp. Chelsea, New York, 1958. $4.95 (bound in 1 volume).

History of the Primates. An introduction to the study of fossil man. W. E. Le Gros Clark. Phoenix Book, Univ. of Chicago Press, Chicago, 1958. 186 pp. $1.25.

Miscellaneous Publications

(Inquiries concerning these publications should be addressed, not to Science, *but to the publisher or agency sponsoring the publication.)*

L'Auto-intoxication après brûlure. T. Godfraind. Université Catholique de Louvain. Arscia, Brussels, 1958. 190 pp.

Some Relationships between U.S. Consumption and Natural Resources, 1899, 1947, 1954. Bureau of Business and Economic Research, Univ. of Maryland, College Park, 1958. 21 pp.

The Air Over Louisville. Summary of a joint report. Special air pollution study of Louisville and Jefferson County, Kentucky, 1956–1957. Robert A. Taft Sanitary Engineering Center, Cincinnati 26, Ohio, 1958. 57 pp.

Catalogue of Type Specimens of Reptiles and Amphibians in Chicago Natural History Museum. Fieldiana: Zoology, vol. 36, No. 4. Hymen Marx. Chicago Natural History Museum, Chicago, 1958. 86 pp. $1.25.

The Role of the College in the Recruitment of Teachers. A report prepared by Frederic W. Ness for the Commission on Teacher Education. Assoc. of American Colleges, Washington, 1958. 83 pp.

The Effects of a Threatening Rumor on a Disaster-Stricken Community. Disaster Study No. 10. Elliott R. Danzig, Paul W. Thayer, Lila R. Galanter. National Acad. of Sciences–National Research Council, Washington, 1958. 116 pp. $2.

The In-Service Training of Science Teachers. A report on the training of out-of-license teachers of general science in New York City. Division of Junior High Schools, Board of Education, of the City of New York, New York, 1958. 68 pp. $0.60.

Tape Editing and Splicing. For the professional and amateur tape recordist. N. M. Haynes. Robins Industries, Flushing 54, N.Y., 1958. 24 pp. $0.25.

Genetics. Laboratory manual. A. M. Winchester. Brown, Dubuque, Iowa, 1958. 128 pp. $2.75.

Engineering and Scientific Education. Foundation of national strength. Conference sponsored by Engineering Manpower Commission of Engineers Joint Council (including American Society for Engineering Education), National Academy of Sciences–National Research Council, National Science Foundation, Scientific Manpower Commission. Scientific Manpower Commission, Washington, 1958. 99 pp. $1.

Archaeological Excavations in the Northern Sierra Madre Occidental, Chihuahua and Sonora, Mexico. Series in Anthropology No. 7. Robert H. Lister. Reports by Paul C. Mangelsdorf and Kate Peck Kent. Univ. of Colorado Press, Boulder, 1958. 121 pp. $3.50.

Orbital Results for Satellite 1957 Beta One. Special Rept. No. 13, Optical Satellite Tracking Program. Luigi G. Jacchia. Smithsonian Astrophysical Observatory, Cambridge, Mass., 1958. 8 pp.

Report on a Study of the Supply of Physics Teachers in U.S. Colleges and Universities Offering a Major in Physics. American Inst. of Physics, New York 17, 1958. 8 pp.

Reports

Serotonin Antagonism of Noradrenaline in vivo

We have previously reported that pretreatment with serotonin reduces the mortality of mice given bacterial endotoxin (*1*). Since the administration of endotoxin is followed by the secretion of, and hypersensitivity to, the adrenalines (*2*), the possibility that serotonin might prove to have antiadrenergic properties was investigated. We have been able to demonstrate that serotonin antagonizes the effect of noradrenaline in four in vivo test systems.

Inhibition of acute noradrenaline toxicity in mice. Serotonin (250 to 450 μg) (*3*) was given to adult male mice (Carworth Farms) averaging 24 g in weight, in 0.1 ml of isotonic saline, divided between the intraperitoneal and subcutaneous routes. Fifteen minutes later 400 μg of noradrenalin were injected intravenously. Control mice, pretreated with saline, were similarly injected with noradrenaline. Serotonin pretreatment reduced the 1-hour noradrenaline mortality from 27/30 to 5/30, and in separate experiments was found to abolish the concomitant pulmonary edema caused by noradrenaline.

Suppression of the mouse pilomotor response. The erector response of the pilomotor muscles may be elicited by the injection of exogenous noradrenaline, or by the release of endogenous noradrenaline following exposure to cold or the injection of reserpine (*4*). We have elicited this reaction by the intramuscular injection of 100 μg of noradrenaline, the intraperitoneal injection of 50 μg of reserpine, or placement of the mouse on a cold metal plate at 1°C. All three methods evoked a response that was reproducible and easy to identify visually. Injection of 250 μg of serotonin intramuscularly 10 minutes before the experiment did not, in itself, cause piloerection and completely suppressed the piloerector response to all three forms of test stimulation. One hundred micrograms of the antiadrenergic compound dibenzyline, when injected intramuscularly, also blocked piloerection, but mecholyl was ineffective.

Lysis of small vessel tone. The local effect of serotonin upon foreleg small vessel resistance was studied in dogs anesthetized with pentobarbital (*5*, *6*). A blood pump interposed between the femoral and brachial arteries maintained foreleg blood flow at a constant rate. Pressures were measured simultaneously, with transducers, in the brachial artery distal to the pump, in a footpad small artery, a paw small vein, and the cephalic vein. Large artery, small vessel (mainly arteriolar), and large vein resistances were separately calculated. In 32 preparations, small vessel neurogenic tone was varied by bilateral vagotomy, foreleg nerve section, and the administration of phentolamine. The administration of 4.5 μg of serotonin per minute, by constant infusion, or of 1.0 μg by instantaneous injection, into the brachial artery decreased small vessel resistance at all levels of tone. The decrement was proportional to the initial level of tone (Fig. 1). In seven other large dogs, after foreleg nerve section, increases in small vessel tone were induced by the infusion of 0.25 to 5.0 μg of noradrenaline per minute into the brachial artery. Infusion of 4.5 to 9.0 μg of serotonin during the noradrenaline infusion decreased elevated small vessel tone in these animals as well.

Inhibition of noradrenaline-induced bradycardia. Continuous heart rate measurements were obtained on pentobarbital-anesthetized dogs given an instantaneous intravenous injection of 10 μg of noradrenaline before and during an intravenous infusion of 300 μg of serotonin per minute.

Noradrenaline, when injected alone, decreased the heart rate during the first 15 seconds by an average of 15 percent. When it was administered during serotonin infusion, noradrenaline increased the heart rate by an average of 15 percent. We have also noted that the tachycardia induced by decreasing the intraluminal pressure of the carotid sinus is abolished during serotonin infusion. These results are similar to the findings of Heymans (*7*) that serotonin, when painted on the carotid sinus, abolishes the sensitivity of the sinus to pressure changes. Since norepinephrine-induced bradycardia is dependent on the carotid sinus reflex and since the denervated heart responds to norepinephrine with tachycardia (*8*), our results are interpreted to mean that serotonin antagonizes the action of norepinephrine upon the carotid sinus.

Our observations that serotonin antagonizes the effects of noradrenaline on four different in vivo test systems suggest strongly that a biological role of serotonin lies in its interaction with the adrenalines. In vitro studies showing that the adrenalines inhibit serotonin-induced contraction of rat uterine smooth muscle (*9*) permit a similar conclusion. Such work emphasizes the negative aspects of the interaction. However, Thomas (*10*) has presented evidence for positive interaction, noting that serotonin enhances skin necrosis due to adrenaline, and Zweifach (*11*) has described a biphasic influence of serotonin on the response to adrenaline in the blood vessels of the rat mesoappendix.

The mechanisms involved in the interaction of these hormones are not clear. The hormones may interact at an organ level through interrelated physiological systems, or perhaps at a molecular level. If the latter occurs, it may be possible to reconcile the above conflicting findings. The in vitro observations of Furchgott (*12*) suggest that serotonin and the adrenalines can compete for biological action sites; thus inhibition might be accounted for on a competitive basis. On the other hand, serotonin and the adrenalines are catabolized by monoamine oxidase (*13*) and ceruloplasmin (*14*); competition for the destructive enzymes might account for potentiation.

Two of our test systems deal with aspects of the cardiovascular system.

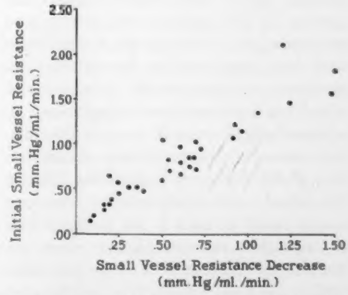

Fig. 1. Serotonin depression of limb small vessel resistance at varying initial levels of neurogenic tone. Serotonin was infused into the brachial artery at the rate of 4.5 μg/min. Thirty-five tests in 22 animals. Initial tone levels were spontaneous or experimentally modified by nerve section high in the limb. Measurements were steady-state.

All technical papers are published in this section. Manuscripts should be typed double-spaced and be submitted in duplicate. In length, they should be limited to the equivalent of 1200 words; this includes the space occupied by illustrative or tabular material, references and notes, and the author(s)' name(s) and affiliation(s). Illustrative material should be limited to one table or one figure. All explanatory notes, including acknowledgments and authorization for publication, and literature references are to be numbered consecutively, keyed into the text proper, and placed at the end of the article under the heading "References and Notes." For fuller details see "Suggestions to Contributors" in *Science* 125, 16 (4 Jan. 1957).

Serotonin antagonism of the effects of noradrenaline may explain certain of the unusual cardiovascular actions of the former compound. Thus, intravenous serotonin is reported to cause systemic hypotension in neurogenic hypertensive animals and hypertension in neurogenic hypotensive animals (*15*). Similarly, in the perfused dog limb, serotonin increases the net resistance across the vessels in limbs with low neurogenic vessel tone and decreases resistance when the initial tone is high (*6, 16*). Apparently, in these preparations, the direction of systemic pressure and peripheral resistance responses to serotonin depends, at least in part, upon initial neurogenic tone.

The reason for this tone dependence in the dog forelimb has been demonstrated to lie in the differing responses of small and large vessel segments to serotonin. Serotonin constricts the large arteries and veins and dilates small vessels (*5, 6*). The magnitude of constriction in large vessels is largely independent of the initial tone, whereas the dilatation in small vessels is directly proportional to the level of initial neurogenic tone. The addition of a fixed, large-vessel constriction to a small vessel dilatation which increases with increasing tone results in a total resistance change which may be dilator or constrictor, depending upon the initial neurogenic tonic input to the small vessels.

The tone of small vessels is in part related to the concentration of noradrenaline at the nerve endings surrounding them. We suggest that serotonin may decrease small vessel tone through its capacity to antagonize the vasoconstrictor activity of noradrenaline on the small vessels. The diverse effects of serotonin upon total resistance changes in the perfused dog limb and upon systemic blood pressure can be explained similarly.

Serotonin and noradrenaline are located in the same areas of the central nervous system (*17*). Noradrenaline depletion (*4, 18*) and the release of bound serotonin (*19*) from the brain stem have both been suggested as mechanisms for reserpine tranquilization. Extension of noradrenaline-serotonin antagonism to a hypothetical critical area in the central nervous system allows reconciliation of the divergent hypotheses. Thus a functional norepinephrine deficiency might result at such a site if the action of available norepinephrine were inhibited by increases in free serotonin (*20*).

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20. Dr. Haddy is a clinical investigator of the Veterans Administration. This investigation was aided by grant No. H-1967 from the National Heart Institute, National Institutes of Health, and by the Ciba Pharmaceutical Co.

14 April 1958

Auxin Action on Coleoptiles in the Presence of Nitrogen and at Low Temperature

Coleoptile elongation is thought to be influenced by the plasticity of the pectic matrix of the cell walls. It is also thought that methylation of pectin increases the wall plasticity by reducing the number of carboxyl groups which may be cross-linked by divalent cations. The balance between methylation by methyl transfer reactions and demethylation by pectin methylesterase (PME) controls the methyl content of pectin. Pectin methylesterase activity in the cell wall is probably reduced by the auxin-mediated binding of the enzyme demonstrated by Glasziou (*1*). Under conditions of active methylation, reduced PME activity would allow an increase in the total methyl content of pectin by reducing hydrolysis of methyl groups. This hypothesis accounts for the effects of auxin on methylation (*2*) and cell expansion. Since auxin-mediated binding of PME is thought to be an adsorption reaction (*1*) it is likely to be insensitive to metabolic conditions. It is also likely that PME activity is less sensitive to metabolic conditions than pectin methylation. The sensitivity of auxin-induced expansion to metabolic control may thus reflect the greater metabolic sensitivity of the methylation process. The results presented in this report are consistent with the above interpretation.

Dark grown wheat coleoptiles (var. Federation) were selected for uniformity of length (± 0.1 cm) in the range 3.0 to 3.7 cm approximately 95 hours after sowing. Sections 2.2 cm in length were cut 3 mm behind the apex, the primary leaf was removed, and the sections were washed in aerated distilled water for 1 to 2 hours prior to treatment. The coleoptiles were treated for 90 minutes in a basal medium of distilled water or 0.02 molar calcium chloride in the presence or absence of 10 mg/liter of unbuffered β-indolylacetic acid (IAA). Each treatment was also carried out in nitrogen or at 2° to 3°C after prior equilibration of the solutions to these conditions and after prior washing of the sections for at least 10 minutes in distilled water equilibrated to either nitrogen or low temperature. After treatment, the sections were trimmed to 2 cm, and deformation under a constant load of 300 mg for 15 minutes was measured (*3*). All manipulations and deformation measurements for the nitrogen treatments were carried out in an atmosphere of nitrogen in a Perspex box fitted with Polythene sleeves. A refrigerated, constant-temperature room was used for the low-temperature treatments, manipulations, and measurements. Coleoptile expansion during each treatment was determined on ten 1-cm sections. A basal medium of calcium chloride solution was used to prevent expansion during treatment in air at 25°C. With turgid material which had not undergone differential expansion, changes in deformability were taken to reflect changes in wall properties.

Significant coleoptile expansion oc-

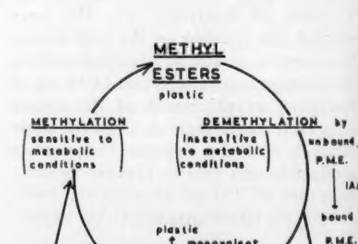

Fig. 1. Possible interconnections between methyl and carboxyl groups of the pectic substances.

Table 1. Effect of treatment with IAA, in the presence of nitrogen or at low temperature in basal media of distilled water or calcium chloride, on deformation of wheat coleoptile sections. Each result is the mean of the deformations of ten sections per treatment. Differences between means were taken as significant at the 5-percent level.

Expt. No.	Basal medium	Mean total angle of deformation (deg)						
		Before treatment (25°C)	After treatment in					
			Basal medium alone	Basal medium + IAA	Basal medium + N_2	Basal medium + N_2 + IAA	Basal medium at 3°C	Basal medium at 3°C + IAA
1	Distilled water	25	27	40	11	23		
2	Distilled water	23	25	38			18	26
3	0.02*M* $CaCl_2$	15	12	16			6	14
4	0.02*M* $CaCl_2$	32	12	17	8	16		

curred only in water or water plus auxin. Deformation data from four representative experiments are shown in Table 1. Treatment with calcium chloride solution caused a significant stiffening of the sections compared with the initial values. In both basal media deformation of auxin-treated coleoptiles was significantly greater than that of sections treated in the absence of auxin. The deformation of coleoptiles treated in nitrogen or at 3°C in a basal medium of calcium chloride solution was significantly less than the deformation of coleoptiles treated in the basal medium alone. Nitrogen also caused a significant stiffening of sections treated in a basal medium of distilled water. The deformation of coleoptiles treated in nitrogen or at 3°C in the presence of auxin was significantly greater than the deformation of such tissue treated in the absence of auxin and was not significantly different from that of coleoptiles treated in basal media alone.

The effect of auxin in reducing wall stiffening in nitrogen and at low temperature suggests an action of auxin which is independent of these conditions, which reduce metabolic activity. The increased wall plasticity and cell expansion which result from auxin action are, however, metabolically dependent. Changes in cell-wall plasticity under different conditions may be interpreted in terms of pectin methylation and demethylation reactions, as is illustrated in Fig .1.

The activity of PME is insensitive to a large number of inhibitors (*4*), and pectin demethylation may occur independently of metabolic conditions. Because of a requirement for adenosine triphosphate, methylation is sensitive to metabolic conditions. A greater sensitivity of methylation compared with demethylation would result in a decrease in the methyl content of pectin in the presence of nitrogen or at low temperature. The increased number of carboxyl groups available for divalent cation binding would result in the observed wall stiffening under such conditions.

The effect of auxin in reducing wall stiffening at low temperature or in nitrogen may be due to an action of auxin which reduces the rate of demethylation and thus conserves the methyl content of pectin. The metabolic insensitivity of the action of auxin which conserves wall plasticity is consistent with Glasziou's hypothesis of an auxin-mediated adsorption reaction which reduces pectin demethylation by reducing PME activity.

It is suggested that the metabolic sensitivity of auxin-induced wall plasticization and cell expansion reflects the sensitivity of the methyl incorporation into pectin and that an auxin action which conserves wall plasticity is independent of metabolic conditions (*5*).

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3. T. Tagawa and J. Bonner, *Plant Physiol.* 32, 207 (1957).
4. Z. I. Kertesz, *The Pectic Substances* (Interscience, New York, 1951).
5. The work described in this paper was carried out during the tenure of a university studentship in plant physiology (D. A.) and senior postgraduate studentship of the Commonwealth Scientific and Industrial Research Organization (H.A.).

18 March 1958

Separation of Tobacco Leaf Proteins by Centrifugation across a Density Boundary

Studies by Wildman and coworkers (*1*) have shown that two major protein fractions are present in green tobacco leaves. The two fractions, I and II, are characterized by sedimentation constants of about 19 and 4 Svedberg units, respectively. Attempts to isolate the fractions have not been wholly successful. A partial resolution can be obtained by salt precipitation (*2*), and fairly pure fraction I has been obtained by repeated ultracentrifugation, but in very low yield and in a highly aggregated form (*3*). This report (*4*) describes a simple procedure for separating the two fractions by ultracentrifugation across a density boundary (*5*).

In principle, a stable boundary is formed by layering a tobacco extract over a buffer-salt solution of greater density. In view of the difference in the sedimentation constants of the two fractions, it is then possible to choose centrifugation conditions such that the faster moving fraction I is completely sedimented, whereas the more slowly sedimenting fraction II moves only a short distance below the initial boundary. After centrifugation the upper portion of the tube should contain only fraction II, and fraction I should be concentrated in the pellet. The middle portion—that is, the region from the initial boundary to that just above the pellet—should contain some fraction II and probably some fraction I because of convection. The procedure and the results obtained in an actual separation run are described below.

The laminar portion of a sample of mature Burley tobacco leaves was lyophilized to a moisture content of 7.66 percent and ground in a Wiley mill. An extract was prepared by grinding 0.3 g of the tissue with 10 ml of 0.2*M* potassium maleate buffer, *p*H 7.5, in a Ten Broeck homogenizer. The buffer contained 0.2 g of $Na_2S_2O_4$ per liter as a color inhibitor, and the extract was maintained at about 7°C throughout the grinding and subsequent manipulations. Seven such extracts were pooled, and cell debris and other insoluble material were removed by centrifugation in a Spinco C rotor at 42,040 rev/min (av. 130,000 *g*) for 1 hour. A thin, oily, green layer at the surface of the liquid was removed by slicing off the upper portion of the Lusteroid tubes with a Spinco tube slicer; the faintly hazy supernatant fluid was then filtered through a 0.5-μ Millipore filter (*6*) to remove the suspended particulate matter. This clarified extract was clear and light brown in color and contained 0.85 mg of N per milliliter, which constituted approximately 60 percent of the total nitrogen of the original sample. A portion of the filtrate was mechanically dialyzed for 6 hours against three portions (two changes) of extraction buffer (without $Na_2S_2O_4$) and then analyzed for total nitrogen and examined in the ultracentrifuge.

For the separation run, seven tubes were prepared. Four milliliters of the clarified extract were added to each tube. A syringe, filled with extraction buffer, which was also 0.2*M* in K_2SO_4, was carefully inserted so that the tip of the needle was close to the bottom of the

tube, and 5 ml of this denser solution was then slowly injected below the extract. A sharp and relatively stable boundary was thus formed between the colored extract and the colorless buffer-salt solution. Centrifugation was carried out in a Spinco C rotor at 42,040 rev/min

Table 1. Ultracentrifugal and analytical data for an extract of green Burley tobacco and for various fractions obtained after separation ultracentrifugation. To facilitate comparison of the data, peak areas and nitrogen values are all expressed in terms of 4 ml of the clarified extract.

Solution	Determination: N (mg)	Fr. I area (cm^2)	Fr. II area (cm^2)
Clarified extract, before separation run	2.06	21.6	54.0
Fractions, after separation run:			
Top 4 ml	0.94		46.0
Middle 4 ml	0.47	4.4	8.4
Lower 1 ml plus pellet	0.60	10.6	2.6
Pellet only, after separation run	0.21	3.2	0.8

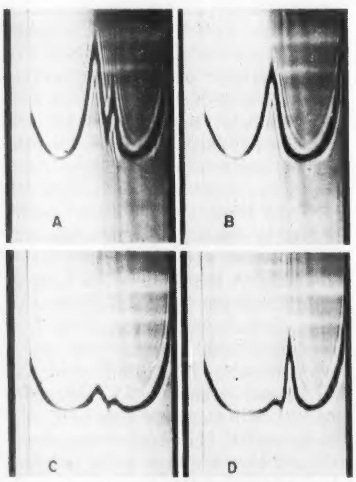

Fig. 1. Schlieren patterns of tobacco extracts to illustrate separation of protein fractions by centrifugation across a density boundary. Sedimentation is from left to right; the faster-moving component is fraction I. *A*, clarified extract before separation run, showing both fractions I and II; *B*, top 4 ml from separation run, pure fraction II; *C*, middle 4 ml from separation run, showing traces of both components; *D*, lower 1 ml of tube plus pellet (solution diluted 1:1 with maleate buffer), primarily fraction I. Patterns photographed at 35° bar angle and 8 minutes after the rotor had reached speed (50, 740 rev/min). Runs were made in a synthetic boundary cell (see *5*) at 25° ± 0.4°C.

for 6 hours at 7°C. The color boundary, which appears to be associated with the movement of fraction II, is blurred somewhat during the centrifugation. By means of the tube slicer, five of the tubes were sampled as follows, and the corresponding fractions were pooled: top 4 ml, middle 4 ml, and lower 1 ml plus pellet. An additional 1 ml of buffer was used to rinse the lower portion of each tube, so that the total volume of the pellet solution was 10 ml. The solutions were dialyzed against maleate buffer as indicated above, and the pellet solution was subsequently centrifuged at 25,000 *g* for 30 minutes at 7°C to remove a small amount of insoluble green material. The two remaining tubes from the separation run were used to examine the composition of the pellet itself. The supernatant fluid was simply decanted, and the pellets were dissolved in a total of 8 ml of maleate buffer. The resulting solution was then dialyzed, and the insoluble green matter was removed as described above. All solutions were analyzed for total nitrogen and examined in the ultracentrifuge.

Sedimentation patterns obtained for the clarified extract and for solutions from the separation run are shown in Fig. 1. Analytical data, including that for the pellet only, are summarized in Table 1. Peak areas, which are proportional to the concentration of the sedimenting components, and sedimentation constants were evaluated from enlarged tracings of the solution and base-line patterns. The areas were corrected for the dilution effect, but Johnston-Ogston corrections (*7*) were not made. The average sedimentation constants determined for fractions I and II were 17 and 3 Svedberg units, respectively.

Analysis of the data shows that the over-all recovery of nitrogen from the clarified extract is 97 percent. The recoveries of fractions I and II, calculated from the peak area measurements, are 70 and 105 percent, respectively. The lower apparent recovery of fraction I is believed to be associated primarily with the uncertainty entailed in estimating the precise volume of the "lower 1 ml" when the tube-slicer technique is utilized. It is also apparent that a major portion of fraction I is suspended in the solution which bathes the pellet and that the fraction I in this solution is not entirely free of fraction II. These factors may be accounted for in terms of sedimentation theory for angle-tube centrifugation and could probably be eliminated or minimized appreciably by the use of a swinging bucket rotor to provide purely horizontal centrifugation.

This relatively simple procedure, with variations, has been carried out many times. The yields of both fractions have been uniformly high, and the preparations of fraction I have been essentially colorless and have been characterized by little or no aggregation (see Fig. 1 *D*). While the present application has been confined to the proteins of green tobacco, the method should be generally applicable to the separation of other mixtures containing macromolecular constituents whose sedimentation constants vary appreciably.

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2. J. Bonner, *Plant Biochemistry* (Academic Press, New York, 1950), pp. 260–61.
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4. This work was sponsored and released for publication by the American Tobacco Company, Inc., Richmond, Va.
5. The separation procedure employed in this study is somewhat similar to that suggested by M. K. Brakke [*J. Am. Chem. Soc.* 73, 1847 (1951)], in which a solution is layered over a solvent having a density gradient. The synthetic boundary cell, developed by E. G. Pickels *et al.* [*Proc. Natl. Acad. Sci. U.S.* 38, 943 (1952)], is based on the same principle except that a solvent of uniform density is layered over the solution.
6. Millipore Filter Corp., Watertown, Mass.
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10 April 1958

Identification of Growth-Promoting α-Hydroxy Fatty Acids Produced by Lactobacillus casei

It was reported in an earlier communication from this laboratory that practically all of the growth-promoting activity in extracts of *Lactobacillus casei* 7469 culture filtrates, as measured with *L. casei* 280-16A (a D-α-hydroxy fatty acid-dependent strain), was associated not with lactic acid but with a more lipophilic substance considered likely to be a higher homolog of lactic acid (*1*). A more rigorous fractionation of such extracts in the present investigation (*2*) has now revealed that they contain at least three growth-promoting acids, two of which appear to be identical with D-α-hydroxyisovaleric and D-α-hydroxyisocaproic acids, respectively.

Lactobacillus casei 7469 was incubated at 35°C for 24 to 96 hours, and the resulting cultures were clarified by passage through a Sharples supercentrifuge. Hydrochloric acid was added (180 meq/liter) to the essentially cell-free solutions, and the acidified media were subjected to continuous liquid-liquid extraction with isopropyl ether. The extracted material from each culture was fractionated by a 200-transfer countercurrent distri-

bution between isopropyl ether and 1*N* hydrochloric acid in a 100-cell Craig-Post apparatus (*3*), and the distribution of organic acids was followed by titrating the material in aliquots of the ether phase with 0.02*N* sodium hydroxide. Growth-promoting activity was determined by microbiological assay of the titrated samples with *L. casei* 280-16A.

The fraction with the highest microbiological activity was that represented by distribution peak D, Fig. 1. It had approximately twice the growth-promoting activity of D-lactic acid and appeared to consist of a single component, which was isolated both as its barium salt and as the free acid. The empirical formulae, $C_6H_{12}O_3$ for the free acid (*4*) and $(C_6H_{11}O_3)_2Ba$ for the salt (*5*), were suggested by the results of microchemical analyses (*4*, *5*), and the corresponding α-hydroxy fatty acid structure, $C_4H_9 \cdot CHOH \cdot COOH$, seemed likely from the *p*H ½ value, 3.8 (*6*), and from previous correlations between structure and growth-promoting activity (*7*).

The five possible racemic (*8*) acids which fit these formulae are DL-α-hydroxy-isocaproic acid, DL-α-hydroxy-*n*-caproic acid, DL-α-hydroxy-DL-β-methylvaleric acid, DL-α-hydroxy-D′L′-β-methylvaleric acid, and DL-α-hydroxy-β,β′-dimethylbutyric acid. The isolated acid was readily distinguishable from the last four of these by marked differences in their infrared absorption spectra. It was indistinguishable from DL-α-hydroxyisocaproic acid on this basis and appeared, therefore, to be identical with the latter compound (see spectra 1 and 2, Fig. 2). It was estimated from the results of semiquantitative experiments that DL-α-hydroxyisocaproic acid constituted approximately 0.2 to 0.3 percent of the total acids produced by *L. casei* 7469. Only the D-moiety of the racemic acid may be

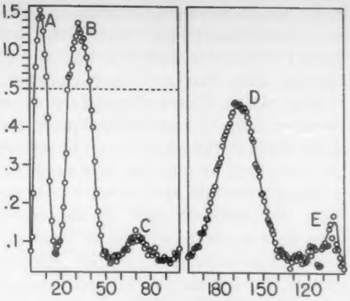

Fig. 1. Countercurrent distribution of acids from a clarified 24-hour culture of *L. casei* 7469 in a 200-transfer experiment. The solvent system consisted of isopropyl ether and 1*N* hydrochloric acid. Values on the vertical scale represent milliliters of 0.02*N* sodium hydroxide required to titrate the acids in 5-ml aliquots of the ether phase solutions (note change of scale at the 0.5-ml level). Numbers on the left horizontal scale designate the cells corresponding to the titrated samples (removed after 200 transfers). Titration values represented on the right side of the figure correspond to samples withdrawn from cell 99 after the designated number (right horizontal scale) of transfers. Distribution peaks A through E correspond to lactic acid, acetic acid (plus unidentified material), α-hydroxyisovaleric acid, α-hydroxyisocaproic acid, and an unidentified (presumably α-hydroxy fatty acid) fraction, respectively (see text).

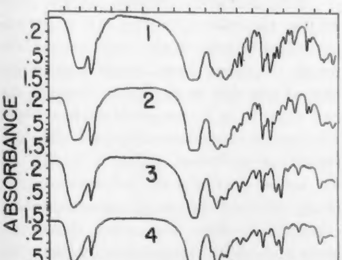

Fig. 2. Infrared absorption spectra of potassium bromide pellet preparations containing barium salts of synthetic α-hydroxyisocaproic acid (curve 1), α-hydroxyisocaproic acid from *L. casei* culture (curve 2), synthetic α-hydroxyisovaleric acid (curve 3), and α-hydroxyisovaleric acid from *L. casei* culture (curve 4).

considered to be a growth-promoting product, for the results of earlier studies have indicated that L-α-hydroxyisocaproic acid probably does not support growth of the test organism (*7*).

The second best growth-promoting fraction (approximately one-third as active as D-lactic acid in this respect) was that represented by distribution peak C, Fig. 1. It appeared to consist of a single component, which was identified as α-hydroxyisovaleric acid by the same procedures as those employed with the α-hydroxyisocaproic acid fraction. The isolated α-hydroxyisovaleric acid was readily distinguishable from α-hydroxy-*n*-valeric acid by marked differences in their infrared absorption spectra, but it was indistinguishable from synthetic α-hydroxyisovaleric acid on this basis (see spectra 3 and 4, Fig. 2). Isopropyl ether solutions of this fraction (concentrates taken directly from the countercurrent extraction apparatus) were distinctly dextrorotatory, and the isolated barium salt was levorotatory ($[\alpha]_D^{25} = -4°$, 1 percent aqueous solution). The $[\alpha]_D$ of purified barium L-α-hydroxyisovalerate (1 percent aqueous solution, 25 to 27°C) is reportedly $-10.1°$ (*9*), and on this basis the *L. casei* product was estimated to consist of approximately 70 percent L- and 30 percent D-α-hydroxyisovaleric acids. L-α-Hydroxyisovaleric acid does not appear to promote growth of the test organism (*7*), and the preponderance of this enantiomorph in the α-hydroxyisovaleric acid fraction was assumed, therefore, to account for the latter's relatively low growth-promoting activity (approximately one-third that of D-lactic acid). L- and D-α-hydroxyisovaleric acids appeared to constitute approximately 0.1 to 0.2 percent of the total acids produced by *L. casei* 7469.

The acids represented by distribution peak E, Fig. 1, did not appear to be homogeneous but had distinct growth-promoting activity (approximately one-fourth that of D-lactic acid) and yielded an average *p*H ½ value of 3.8. It seemed quite likely, therefore, that this fraction contained at least one additional D-α-hydroxy fatty acid. This fraction and those represented by distribution peaks A (lactic acid) and B (acetic acid plus unidentified components) are under further investigation (*10*).

The functions of D-α-hydroxy fatty acids in *L. casei* are far from clear. Our present working hypothesis is that they are metabolic precursors of cerebrosides since the latter from both mammalian and microbial sources are conspicuous for their content of 22–26 carbon D-α-hydroxy fatty acids (*7*). Whether the D-α-hydroxyisovaleric and D-α-hydroxyisocaproic acids produced by *L. casei* are concerned in vital metabolic processes of this nature or whether they are merely accidental by-products of amino acid metabolism (theoretically derivable from valine and leucine, respectively) appear to be important questions, which we hope may be resolved by the experimentation now in progress.

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2. This investigation (No. 124) was aided by grants from the National Multiple Sclerosis Society, the U.S. Public Health Service, and the University of California. We are indebted to Evelyn Brown, James Gilbert, and Claus Becker for technical assistance, to Donna M. Karasek for infrared spectrography, and to Heather King for microanalyses.

3. The analytical instrument employed had a capacity of 10 ml of each phase per cell. Preparative work was carried out with a larger apparatus (capacity 40 ml of each phase per cell), which was made available through the courtesy of Dr. John G. Pierce and the Department of Physiological Chemistry, University of California, Los Angeles.
4. Carbon: calculated 54.5 percent; found, 54.7 and 54.8 percent. Hydrogen: calculated 9.15 percent; found, 8.65 and 9.14 percent. Equivalent weight: found, 134.7 (formula weight 132.2).
5. Barium: calculated, 34.4 percent; found, 33.8 and 34.0 percent.
6. Estimated from the titration curve. This value is characteristic of simple α-hydroxy acids. The corresponding unsubstituted acids yield much higher values, and the β-hydroxy acids give values approximately halfway between those

of the unsubstituted and α-hydroxy acids. Divalonic acid (a six-carbon, growth-promoting β-hydroxy acid), for example, exhibits a pH ½ value of 4.3, according to Wolf *et al.* [*J. Am. Chem. Soc.* 78, 4499 (1956)].
7. M. N. Camien and M. S. Dunn, *J. Biol. Chem.* 211, 593 (1954).
8. Neither the isolated barium salt (2 percent in water) nor the free acid (2 percent in either water or chloroform) yielded a significant optical rotation with sodium light.
9. C. G. Baker and A. Meister, *J. Am. Chem. Soc.* 73, 1336 (1951).
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11 April 1958

Daily Rhythms in Male Harvester and Argentine Ants

The nuptial flights of various species of ants occur at characteristic times—for example, in a species of *Myrmica,* early morning; of *Lasius,* late afternoon (*1*); of *Eciton,* night (*2*). To gain a better understanding of such field observations, male and female harvester ants [*Veromessor andrei* (Mayr)] and male Argentine ants [*Iridomyrmex humilis* (Mayr)] (*3*) were studied in a constant-temperature room in alternating light and dark (*4*). Under these conditions, as is shown below, the males of both species exhibited a sharp daily activity peak, but at opposite ends of the light period.

The *Veromessor* females were obtained at a nest entrance on 26 July and kept until September with workers under room conditions (about 19° to 26°C). The males were collected at the entrance of the same nest on 13 September and kept by themselves.

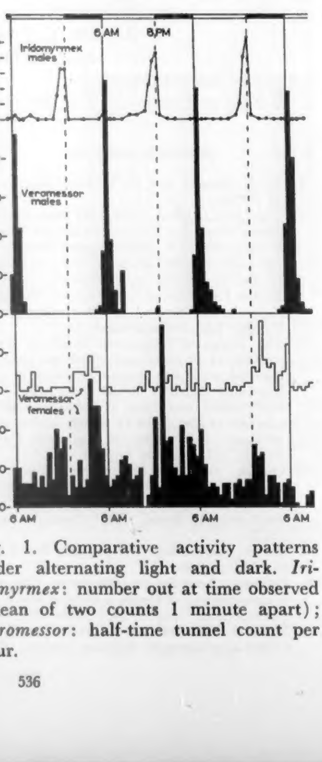

Fig. 1. Comparative activity patterns under alternating light and dark. *Iridomyrmex*: number out at time observed (mean of two counts 1 minute apart); *Veromessor*: half-time tunnel count per hour.

To obtain automatic activity samples, a circular "race track" was used. Two lots of ten males and two lots of ten females were placed in tiny chambers of clear plastic. Cotton-plugged test tubes of water and of sugar water projected down through the roof of each chamber; no other food or moisture was supplied. A transparent tube circled from one exit from the chamber back to the other, narrowing midway between to form the lining of a polystyrene tunnel. An ant passing through the tunnel, and thus between "sensitive" and "ground" screws, triggered a capacity-operated relay. In another room the total number of passes was recorded on a digital counter which was photographed each hour.

Since there were only two such relays available, a motor-driven cam device was used with each to alternate the contacts between two tunnels, so that a group of males were counted for half a minute, then females, and so forth. Thus each machine made a half-time count for each sex (*5*).

To simulate the darkness of the normal nest, the entire chamber was covered by an orange Plexiglas box (*6*). The circular "track" was left fully exposed to the light.

The counts of *Iridomyrmex* males, on the other hand, were made on a complete colony, consisting of nest queens, numerous workers and young, and about 14 males. The nest had been under laboratory conditions for over a year. Two adjacent plaster units opened onto a common board, which had legs set in DDT (*7*). The microscope-slide roof of each unit was overlapped with orange Plexiglas (*6*). Water and sugar water were continuously available in tubes suspended from a post set on the board (*7*). Solid food was provided, and the plaster was moistened, at irregular (though recorded) times; this had no observable effect on the rhythm. The males came out and wandered over the units or near them. Their wings made them easy to spot, and the total out at any given time was counted by eye.

Both species were kept on the same table in a darkroom at 25.4° ± 0.4°C. A 40-watt fluorescent light, automatically turned on at 6 A.M. and off at 8 P.M., provided an intensity of about 50 ft-ca. Two 40-watt clear ruby darkroom lights (two feet from the ants) were on continuously. Mechanical disturbance was minimized by sponge-rubber pads.

Figure 1 shows the simultaneously recorded activity patterns from 30 September to 3 October 1957, after the ants had been under the experimental conditions for several days. The replicate pattern of *Veromessor* males was similar to the one shown. Both female counts are given because of their greater variability. In fact, the activity patterns of the females are of interest, under these particular conditions, principally because of their lack of well-marked peaks, by contrast with the males.

The activity peak of *Veromessor* males occurred the first hour of each light period and was preceded consistently by a rise the last hour of the dark, with relative quiet the rest of the time (*8*). The *Iridomyrmex* males, on the other hand, were out of the nest during the last 2 hours of the light period only. The increases in activity *before* the changes in lighting suggest endogenous control of the rhythms. Further evidences for such an internal "clock" (*9*) in both species studied here were (*10*): (i) persistence of rhythm in constant darkness (that is, red light), though the *Veromessor* peak averaged 0.5 to 1 hour later each day, and (ii) a shift of phase following a single 5 P.M.–5 A.M. light period.

Veromessor mating flights occur locally early in the morning (*10*), thus suggesting the significance of the laboratory activity peaks. A species-characteristic light-phase relationship would seem valuable in synchronizing the nuptial flights of colonies of the same species. However, simple environmental response to the dawn might be insufficient, unless the ants were near enough to the surface at the right time. Endogenous control could bring them to the entry in time for the dawn. Their clocks could be "set" when the winged ants emerge on nonflight days, as do *Veromessor* (and other ants—for example, see *1, 11*). Such inherent control was postulated for worker leaf-cutting ants which were in the nest entry 1 hour before dawn, though even artificial light would not bring them up earlier (*12*). Similarly, bees trained to forage at a certain time may remain in a remote part of the hive until shortly before that time (*13*).

The value of the clocklike emergence of *Iridomyrmex* males is more difficult to explain, since mating takes place within the nest (*7, 14*). If a general male-and-female flight ever occurs, the results reported here would suggest the end of the day as the time. Perhaps the exit rhythm is a vestige of such a flight. The males sometimes fly, and they are found at artificial lights (*7, 14*). If the males normally fly before mating, a clock with the phase relationship noted could bring them out when late afternoon and night remain for encountering another nest or column of workers, before it again becomes too hot or dry for survival. In certain army ant species, where the virgin queens are wingless, some of the males, after their night flights, find their way into other colonies (*2*).

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2. T. C. Schneirla, *Zoologica* 33, 89 (1948).
3. Determined by M. R. Smith, U.S. Department of Agriculture.
4. I am indebted to A. C. Giese, under whose direction this work was done, and to C. S. Pittendrigh for helpful discussions.
5. The contact was damped each minute by flexible contact arms. The male rhythm was checked later after some days in constant darkness (that is, red light) by turning off the alternators, and it was found to persist as before.
6. The Plexiglas permitted good visibility, but, to judge from the color choices made by *Iridomyrmex* workers with queens and brood, it was nearly as "dark" as a black cover.
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* On leave from the College of Medical Evangelists, Loma Linda, Calif.

31 March 1958

New Metabolites of Serotonin in Carcinoid Urine

5-Hydroxyindoleacetic acid, the only metabolite of serotonin so far identified, represents less than 20 percent of an exogenous dose of serotonin (*1*). The reported presence of other unidentified indole derivatives in carcinoid urines (*2*) and rat liver perfusates (*3*), however, is indicative that metabolic reactions other than deamination occur. Suggestive evidence has also been presented that free serotonin is present in normal urine (*4*). Now it has been found that carcinoid urine is much more oxytocic than normal urine (personal observation) and it was thought that, if in this syndrome there was an increase in the excretion of the known metabolite, there would also be an increase in the unknown metabolites.

By an adaptation of the method described by Bumpus and Page (*4*), the indoles were extracted from 3 gal of carcinoid urine from one patient which contained 350 mg of 5-hydroxyindoleacetic acid as assayed by the method of Udenfriend, Titus, and Weissbach (*5*). Removal of excess urea and a partial fractionation of indoles was accomplished by using a cellulose column and a single phase solvent of *n*-propanol/ammonia.

Paper chromatography of the concentrated extracts and fractions revealed the presence of six indole derivatives. Five of these were identified by means of paper chromatography in three solvents, oxytocic activity, and fluorescent spectra (see Table 1). One of these proved to be the normally occurring urinary indican, but the other four—5-hydroxyindoleacetic acid, 5-hydroxyindoleaceturic acid, 5-hydroxytryptamine and N-acetyl 5-hydroxytryptamine—were evidently metabolites by serotonin. The 5-hydroxyindoleaceturic acid was further characterized by enzymic hydrolysis of an eluate with chymotrypsin, to yield 5-hydroxyindoleacetic acid and glycine.

Table 1. R_F values, oxytocic activity, and fluorescent spectra of metabolites of serotonin and the normally occurring urinary indican.

Metabolite	R_F in solvent*			Oxytocic† activity	Fluorescent spectra (mμ)‡		
	A	B	C		Activation (max.)	Fluorescent (max.)	pH
Serotonin creatinine sulphate	0.48	0.64	0.86	+++	295	540	2
5-Hydroxyindoleacetic acid	0.15	0.80	0.03		300	355	7
5-Hydroxyindoleaceturic acid	0.23	0.84					
N-acetyl serotonin	0.75	0.81	0.86	±	310	370	7
Indican	0.40	0.43	0.56		300	400	7

* Blue spots were obtained when sprayed with *p*-dimethylaminobenzaldehyde in 1.5*N* HCl. Solvent systems used: A, propan-1-ol saturated with ammonia; B, *n* butanol–acetic acid–water (4:1:5); C, ethyl methyl ketone–2*N* ammonia (2:1).
† Oxytocic activity was determined on an eoestrus rat uterus. Activity was antagonized by brom-lysergic acid diethylamide.
‡ Fluorescent spectra were determined with an Aminco Bowman spectrophotofluorometer.

The metabolism of endogenous serotonin in carcinoid patients therefore appears to be very similar to that of exogenous serotonin in experimental animals which we have studied (*6*). Autoradiographs obtained from urinary extracts of rats and rabbits given radioactive serotonin have shown the presence of the same four metabolites with the addition of two other minor metabolites. One of these has been identified as the glucuronide of serotonin since it gave a positive indole test but did not give a blue color with 2:6 dichloroquinonechloroimide, indicating that the hydroxyl group was not free. An eluate of this compound gave a positive naphthoresorcinol reaction, confirming that it was an ether glucuronide. Quantitative estimations of glucuronic acid and ethereal sulfate excretion after administration of serotonin have also shown that some conjugation does take place.

Oxidation of serotonin in vivo is a theoretical possibility, and it was thought that the other minor metabolite might represent the product of such a reaction, though so far no definite experimental confirmation has been obtained since it is present in such small quantities.

No evidence has been found in these experiments to suggest that methylation of serotonin might occur.

The normal metabolic fate of serotonin therefore appears to be (i) deamination to 5-hydroxyindoleacetic acid with (ii) some subsequent glycine conjugation to form the aceturic acid, (iii) N-acetylation, (iv) conjugation with glucuronic acid, (v) excretion unchanged and (vi) possible oxidation.

Preliminary studies have shown that, although great amounts of serotonin are metabolized by carcinoid patients, there appears to be no qualitative difference from the normal mode of metabolism.

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14 April 1958

Spontaneous Changes in Corn Endosperm Tissue Cultures

Spontaneous changes in the characteristics of plant tissue cultures are known to occur from time to time. The best documented change is that which occurs in connection with the isolation of habituated tissues (*1*). Habituated tissues are independent of exogenous auxin, in contrast to the normal tissues from which they are derived. The latter tissues require external supplies of auxin for growth in vitro. Another change which has been observed to arise is the appearance of a purely parenchymatous tissue from woody tissue cultures (*2*). Reinert (*3*) and Torrey (*4*) have described irreversible changes from compact calli to cultures of very loose masses of cells from *Picea* and pea root callus, respectively. The latter changes, however, were as-

cribed to manipulations of the nutrient medium. In this report changes in the characteristics of corn endosperm tissue cultures are described which cannot be ascribed to manipulations of the nutrient medium.

Sternheimer (5) announced the establishment of tissue cultures of an anthocyanin-bearing strain of maize endosperm and a nonpigmented tissue derived from the same pigmented tissue. Mrs. Sternheimer was kind enough to supply me with cultures of these tissues in 1953. Unfortunately, these tissues were lost through accident and new cultures were subsequently isolated.

The endosperm was isolated from the maize variety Black Mexican Sweet according to the methods of Straus and LaRue (6). The culture medium and methods for determining changes in weight are described in the same paper.

Colorless tissues arise with a frequency of about 1 in 4000 cultures of pigmented tissue. The frequency is raised somewhat if old pigmented cultures which have ceased growth are transferred to fresh medium. The change from pigmented to nonpigmented tissue is not entirely irreversible. Occasional nonpigmented cultures show discrete, small spots of pigmentation. Attempts to isolate and grow these pigmented spots have consistently failed. This is probably due to their very small size (0.5 to 1.0 mm) and hence to their inability to grow when separated from the main mass of tissue. The pigmented spots never get very large and are soon outgrown by the colorless tissue.

The nonpigmented tissue (PI-C) has a growth rate very nearly double that of the pigmented tissue (PI). In 25 days PI-C shows a 475 percent increase in fresh weight and PI a 246 percent increase. Auxin (1 mg per liter of indoleacetic acid) inhibits the growth of both tissues, so it is doubtful that the increased growth rate of PI-C represents the same type of habituation as is found with other tissue cultures. If PI tissues were stimulated to grow more rapidly by addition of auxin, then habituation of the PI-C tissue would seem reasonable.

Extracts of PI-C prepared by disintegrating the tissues in a blender with sufficient 95 percent ethanol to give a final concentration of 80 percent ethanol, by evaporating at room temperature, and by taking up the residue in water and adding it to the nutrient medium stimulate the growth of both tissues in the presence of casein hydrolyzate (2 g/lit.). The increase in growth is small (10 percent) but persistent and highly reproducible. Extracts of PI tissue, on the other hand, are growth inhibiting under the same circumstances. These extracts depress growth by 18 to 38 percent. The results obtained with the PI extracts are not as quantitatively reproducible as those obtained with PI-C, but there is a persistent growth inhibition.

Another change has been observed in the PI tissues more recently. Early in 1958, several cultures of PI were found to have a bright red color rather than the deep purple normally found in the PI tissues. The red tissue (PI-R) has been subcultured six times at the time of writing and has persisted in producing the red pigment. No quantitative experiments have been performed to determine whether there is any difference in growth rate between PI and PI-R. However, visual observation does not indicate any great difference in the growth characteristics of the two tissues.

Absorption spectra of extracts prepared by steeping PI tissue in 95 percent ethanol containing 2 percent concentrated HCl (vol./vol.) to extract the pigments show two absorption maxima, one at 325 mμ and one at 530 to 540 mμ. The near-ultraviolet peak is characteristic of the flavone pigments, and the peak at 530 to 540 mμ is characteristic of some anthocyanins (7). Extracts of PI-R show a shift in both maxima to 340 mμ and 520 mμ. Preliminary purification of extracts of both PI and PI-R was attained by chromatography (see below) and subsequent elution of the major bands. Spectra taken of these purified pigments showed only the maxima in the longer wavelengths: 540 mμ for PI and 520 mμ for PI-R. Extracts of PI-C tissue show only the peak at 325 mμ. Extracts of CE clone I-C (6) which is derived from a corn endosperm that is normally unpigmented show no absorption peaks over the wavelengths tested (310 to 600 mμ). It appears, then, that pigments closely resembling anthocyanins are still synthesized by the PI-C tissues, but the ability to synthesize anthocyanin has been lost.

Extracts of the three tissues (PI, PI-C, and PI-R) were examined chromatographically. The extracts were prepared in the same manner as those used for the spectrophotometric observations. The crude extracts were evaporated at room temperature in an air stream, and the residue was repeatedly extracted with 95 percent ethanol. The ethanol solution was filtered and spotted on sheets of washed Whatman No. 1 filter paper. The sheets were equilibrated for 8 hours with the lower phase of *n*-butanol: acetic acid: water (4:1:5). The paper was then irrigated (descending) with the organic phase of the same mixture for 12 hours at a temperature of 30°C. Extracts of the three tissues were cochromatogrammed on the same sheet.

PI and PI-R tissues have mixtures consisting of at least three anthocyanins. The three pigments are common to both tissues. However, there was one spot representing the major pigment for each tissue. For PI, the main pigment spot had an R_f of 0.36; for PI-R the R_f of the main pigment spot was 0.47. Both tissues showed both pigment spots, but in PI the spot at 0.47 was very faint and the PI-R spot at 0.36 was also very faint. Both tissues revealed a barely discernible pigment spot at R_f 0.3. Partial hydrolysis of the major PI pigment with HCl and subsequent chromatography showed that the spot at R_f 0.47 was not the aglycone; the aglycone had an R_f of 0.62. The chromatographic evidence, together with the absorption data, seems to indicate quite strongly that PI-R tissue is synthesizing an anthocyanin quite different from that produced by the PI tissue. Unfortunately none of the pigments have been positively identified yet.

Examination of the chromatograms with ultraviolet light revealed fluorescing spots which were common to all three tissues.

The evidence seems to point to definite spontaneous changes occurring in the endosperm of Black Mexican Sweet cultured in vitro. The change to colorless in the tissue cultures seems to involve a lack of synthesis of anthocyanin from the precursor common to both the anthocyanins and flavonols. The absorption at 325 mμ seems to indicate that the precursors or flavonols are still synthesized by PI-C tissue.

Whether the changes described are due to gene mutations or to chromosomal abnormalities cannot at present be stated definitely. Chromosome smears of PI, PI-C, and PI-R tissues reveal the same types of aberrant nuclear and chromosomal behavior as that described for CE clone I-C (8). These are a high frequency of chromosome bridges, lagging chromosomes, regular and irregular polyploidy, hypoploidy and multinucleate cells. It would appear, then, that there are many opportunities for changes in the characteristics of the tissue to occur due to chromosomal abnormalities (9).

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16 June 1958

Association Affairs

AAAS Finances: Report for 1957

During 1957 the income of the American Association for the Advancement of Science for its normal and continuing operating expenses amounted to $835,716.13. This amount was divided as follows:

Annual dues paid by members	$320,084.91
Extra payments by members who wanted to receive both *Science* and *The Scientific Monthly*	22,312.41
Money transferred from the Investment Account to pay for subscriptions for emeritus and life members	3,933.00
Subscriptions to *Science* by nonmembers	52,749.28
Subscriptions to *The Scientific Monthly* by nonmembers	21,076.04
Sales of single copies and back issues	4,595.28
Advertising in *Science* and *The Scientific Monthly*	264,456.88
Sales of symposium volumes	56,417.74
Annual meeting: registration fees, exposition space, advertising in program, and contributions	27,073.31
Income from investment of funds not needed in checking account	11,472.23
Rental income from third floor and garage of new building	21,966.51
Allowance for expenses incurred in administering grants	21,094.70
Miscellaneous receipts	8,483.84
Total	$835,716.13

These receipts amounted to $10,914.10 more than the operating expenses. The principal items of expense were:

Printing and editing *Science* and *The Scientific Monthly*	$438,809.90
Cost of selling advertising in the two journals	68,614.22
Printing and editing symposium volumes	35,737.80
Expenses of the annual meeting	36,278.06
Allowances ($1 per member) to Pacific, Southwestern and Rocky Mountain, and Alaska divisions	8,196.00
Expenses of AAAS sections	3,736.67
Board of Directors' meetings	4,172.60
Meetings of committees	3,610.73
Administrative and general expense	40,052.37
Business office, salary and other expenses	94,261.24
Circularization of new members (exclusive of salaries)	10,154.14
Building maintenance	34,654.50
Real estate taxes	12,908.52
Depreciation allowance on building	23,547.27
Depreciation allowance on equipment	5,508.58
Allowance for uncollectable items	2,000.00
Miscellaneous other expenses	2,559.43
Total	$824,802.03

The excess of income over expense of $10,914.10 requires explanation. During 1957 the Association changed its method of handling some of its accounts receivable from a cash basis to an accrual basis. At the end of the year, close to $9000 of accounts receivable were shown as having accrued to the Association, even though the money had not actually been received. The comparable amounts in earlier years were not shown until the money was actually received. Therefore, under the bookkeeping system used in years before 1957, the excess of income over expense would have been approximately $2000 instead of approximately $11,000.

In considering the excess of income over expenses, it should also be taken into account that over $29,000 of expense consists of money set aside for depreciation of the building and its equipment.

Comparison of 1957 with 1956

Receipts in 1957 were $116,482.32 above those for 1956. An increase of $49,573.60 in advertising revenue was the largest contributor to the difference. Other substantial increases were $14,081.39 in annual dues payments; $7,760.29 in nonmember subscriptions; $35,402.52 from the sale of symposium volumes; and $10,615.86 more from rental of space in the Association's building (the space was rented for a full year in 1957 and for only part of 1956). The only major decrease in income consisted of receipts of $14,833 less from the 1957 meeting in Indianapolis than from the previous year's meeting in New York City.

The details of the 1956 account are given in the 13 September 1957 issue of *Science* [**126**, 519 (1957)].

Expenses for 1957 totaled $106,796.18 more than in 1956. The bulk of this increase was accounted for by the Association's publications. Printing and editing *Science* and *The Scientific Monthly* cost $54,222.78 more than in 1956. The cost of selling a larger amount of advertising was $14,107.26 greater than in 1956. Building maintenance was approximately doubled, for the new building was maintained for a full year instead of the seven months that it was occupied during 1956. For the same reason, the amount charged off as depreciation against building and equipment was approximately twice as great in 1957 as in 1956. Expenses of the business office and the Association's general administration were $12,363.33 greater in 1957 than in 1956.

Grants Administered during 1957

Grants amounting to $340,127.37 were administered by the Association during 1957. This total includes $239,060 of new money received during the year and a balance of $101,067.37 on hand at the beginning of 1957 from grants received earlier.

Largest in amount was the grant from the Carnegie Corporation for the Science Teaching Improvement Program. That grant of $300,000 extended over a three-year period. The final payment of $100,000 was received on 1 July 1957. Expenses during the year amounted to $89,749.10. The balance at the end of the year was $68,403.95. Also on hand at the beginning of the year was $10,267.50 from a supplementary grant from the General Electric Educational and Charitable Fund, of which $7386.64 was spent during the year, leaving a balance of $2880.86.

From the National Science Foundation's grant to support the Traveling Science Libraries, the Association had on hand at the beginning of the year $28,406.27. A new grant of $113,960 was received in 1957. Expenses of $98,440.67 left a balance of $43,925.60.

During 1956 the Association received a grant from the Carnegie Corporation to pay the cost of two conferences on mathematics instruction. The second of those conferences was held during 1957, at a cost of $3506.09. The unexpended balance of $734.46 was returned to the Carnegie Corporation.

During 1957 the Association received a grant of $20,000 from the Ford Foundation toward the expenses of a study of possible changes in income tax provisions to encourage private contributions

for educational and similar purposes. The study was conducted by the Surveys and Research Corporation of Washington. Expenses up until the end of 1957 amounted to $17,331.51, leaving a balance at the end of the year of $2668.49.

Also during 1957 the Association received a grant of $5100 from the National Science Foundation to help pay the expenses of a conference of representatives of junior academies of science. The grant was totally expended for that conference.

Investment Account

To keep them separated from current funds and from grants for special activities, the Association holds its endowment and investment funds in a separate Investment Account. At the end of 1957 this account included the following:

Cash	$ 14,476.60
U.S. Government bonds	66,206.25
Industrial bonds	145,969.55
Preferred stocks	58,908.59
Common stocks	209,013.94
Total	$494,574.93

The above figures are at cost or book value, rather than at the market value of the securities. The total is $43,206.42 greater than was the book value one year earlier.

During the year the Association received $18,627.82 in dividends and interest on its Investment Account. This income represents a return of 3.8 percent on the book value of the account at the end of the year and slightly better than 4.1 percent on the book value at the beginning of the year.

The income was used as follows:

Investment counsel and cost of servicing securities	$ 1,815.74
Grants to affiliated academies of science	4,089.50
Transferred to operating fund for life and emeritus members	3,933.00
To the Gordon Research Conferences	2,041.33
Award of Newcomb Cleveland Prize	1,005.00
Award of Socio-Psychological Prize	1,008.83
Increase in value of endowment funds	4,734.42
Total	$18,627.82

During the year the Association also gained $18,669.02 from the sale of securities. This amount, plus the $4734.42 shown in the table above, plus the fees of new life members ($7155), plus a small amount received in the form of gifts during the year, and plus an increase of $11,670.05 in funds held for the Gordon Research Conferences, accounts for the total increase in book value of $43,206.42 quoted above.

Consolidated Balance Sheet

In order to give a view of the Association's financial position, the figures from the Current Fund and Investment Account have been combined here. At the end of 1957, the consolidated balance sheet showed the following assets:

Cash on deposit:	
Operating account	$ 155,465.01
Investment account	14,476.60
Investments at cost:	
Operating account	411,398.59
Investment account	480,098.33
Land	115,875.00
Building (less depreciation)	746,733.19
Equipment (less depreciation)	51,132.05
Money owed to the Association	59,379.96
Total	$2,034,558.73

These assets were partially offset by the following liabilities:

Prepaid dues and subscriptions for which members and other subscribers had not yet received journals or other services	$358,910.95
Unexpended balance of grants from the Carnegie Corporation, the General Electric Educational and Charitable Fund, the National Science Foundation, and the Ford Foundation	117,878.90

Accounts payable to others	89,170.41
Remainder of mortgage on building, payable in 8½ years	$152,979.56
Held for Gordon Research Conferences	38,172.80
Total	$757,112.62

The difference between the assets and liabilities represents the Association's net worth. As of the end of 1957, the net worth was distributed as follows:

Endowment funds:	
For research	$ 201,292.02
For general purposes (used to pay subscription costs for life and emeritus members)	190,728.90
For the Newcomb Cleveland Prize	27,180.95
For the Socio-Psychological Prize	29,026.65
For creating emeritus life memberships	8,173.61
Value of land	115,875.00
Value of building (less depreciation and mortgage)	593,753.63
Unallocated reserve	115,599.63
Total	$1,277,446.11

This net worth figure is $41,914.20 greater than at the end of 1956.

Auditor's Report

The Association's financial records for 1957 were audited by the firm of G. P. Graham and Company. The tables presented above differ in form from those included in the auditor's report, and the explanations of sources of income and nature of expense are usually given in greater detail. In a few cases, items have been reclassified from the auditor's report to make more meaningful groupings. Except for such rearrangements, there are no differences between the figures presented here and those reported in the audited account, to which was attached a letter reading, in part: "In our opinion the accompanying statements present fairly the financial position of the American Association for the Advancement of Science as at December 31, 1957, and the results of its operations for the year ended on that day, and were prepared in conformity with generally accepted accounting principles. . . . Respectfully submitted, G. P. Graham and Company, by G. R. Bowers."

DAEL WOLFLE

American Association for the Advancement of Science

International Conference on the Peaceful Uses of Atomic Energy

The Second United Nations International Conference on the Peaceful Uses of Atomic Energy at Geneva, Switzerland, began on 1 September and will continue through 13 September. Formal invitations to take part in the 1958 con-

ference were sent by the United Nations to 88 governments and the affiliated specialized agencies. Sixty-one governments are participating.

Plans for the conference were developed by a seven-nation advisory committee, including scientists from Brazil, Canada, France, India, the U.S.S.R., the United Kingdom, and the United States. Sigvard Eklund, Secretary-General of the conference, appointed a 21-member scientific secretariat from 13 countries to assist in the preparation of the agenda. Subjects that are receiving major attention at the conference are basic nuclear physics, including nuclear fusion, nuclear reactors, chemistry, radioisotopes, health and safety problems, raw materials, and metallurgy.

The U.S. delegation, announced by President Eisenhower on 20 August, includes Lewis L. Strauss, chairman, James R. Killian, Jr., Willard F. Libby, Robert McKinney, and I. I. Rabi. Representatives of the Joint Congressional Committee on Atomic Energy are also attending and the U.S. delegation has an advisory scientific group of approximately 200 scientists.

This country is presenting more than 700 papers, of which approximately 200 are being presented orally, while the rest will appear in the printed procedure. The U.S. exhibit covers about 36,000 square feet of space and includes four major sections: Basic Sciences, Life Sciences, Fission Reactors, and Controlled Fusion Research. A total of 44 films on many aspects of atomic energy utilization have been produced by the U.S. for the conference, and a U.S. Technical Information Center is available for the use of delegates from all countries.

More than 40 private American industrial firms are taking part in a commercial exhibit that is being held in Geneva at the same time as the conference. The exhibit displays atomic energy equipment, components, products, and services that are now available on the open market.

Forthcoming Events

October

5–8. American Inst. of Mining, Metallurgical, and Petroleum Engineers, fall, Houston, Tex. (E. O. Kirkendall, AIME, 29 W. 39 St., New York 18.)

6–9. Veterinary Public Health Practice, 1st inst., Ann Arbor, Mich. (H. E. Miller, Continued Education, School of Public Health, Univ. of Michigan, Ann Arbor.)

6–11. Electroencephalographic Study of the Higher Nervous Activity Processes in Animals and Man, colloquium (by invitation), Moscow, U.S.S.R. (Miss Mary A. B. Brazier, Massachusetts Neurophysiological Laboratory, Massachusetts General Hospital, Boston 14.)

7–9. Hypervelocity, 3rd symp., Chicago, Ill., (Air Force Office of Scientific Research, Air Research and Development Command, U.S. Air Force, Washington 25.)

7–9. International Soc. for the History of Pharmacy, cong., Venice, Italy. (A. F. Vitolo, Piazza Carrara 10, Pisa, Italy.)

8–12. Nutrition and Vital Substances, 4th intern. conv., Essen, Germany (Secretary General, Bemeroder Strasse 61, Hannover-Kirchrode, Germany.)

10–11. Association of Midwest Biology Teachers, Western Illinois Univ., Macomb. (R. M. Myers, Western Illinois Univ., Macomb.)

11–15. Salinity Problems in the Arid Zones, UNESCO symp., Tehran, Iran. (UNESCO, 19, avenue Kleber, Paris 16e.)

12–17. American Acad. of Ophthalmology and Otolaryngology, Chicago, Ill. (W. L. Benedict, 100 First Ave. Bldg., Rochester, Minn.)

13–15. Association of American Medical Colleges, 69th annual, Philadelphia, Pa. (W. Darley, AAMC, 2530 Ridge Ave., Evanston, Ill.)

13–15. National Electronics Conf., Chicago, Ill. (L. W. Von Tersch, Michigan State Univ., East Lansing.)

13–16. Society of Exploration Geophysicists, 28th annual intern., San Antonio, Tex. (C. C. Campbell, Box 1536, Tulsa 1, Okla.)

13–17. American Soc. of Civil Engineers, annual conv., New York, N.Y. (W. H. Wisely, ASCE, 33 West 39 St., New York 18.)

15–17. American Ceramics Soc., Glass Div., Bedford, Pa. (C. S. Pearce, 4055 N. High St., Columbus 14, Ohio.)

19–22. Land and Water, Soil Conservation Soc. of America, 13th annual, Asheville, N.C. (H. W. Pritchard, 838 Fifth Ave., Des Moines 14, Iowa.)

19–24. American Soc. of Anesthesiologists, Pittsburgh, Pa. (J. E. Remlinger, 802 Ashland Ave., Wilmette, Ill.)

19–26. Allergology, 3rd intern. cong., Paris, France. (S. M. Feinberg, Medical School, Ward Memorial Building, 303 East Chicago Ave., Chicago, Ill.)

19–26. Medical Hydrology, 21st intern. cong., Madrid, Spain. (Dr. Francon, 55, rue des Mathurins, Paris 8e, France.)

20–21. Rubber and Plastics Instrumentation, natl. symp., Akron, Ohio. (D. R. Davis, General Tire and Rubber Co., Central Research Lab., Akron 9.)

20–22. American Oil Chemists' Soc., fall, Chicago, Ill. (Mrs. L. R. Hawkins, 35 E. Wacker Drive, Chicago 1.)

20–23. American Acad. of Pediatrics, Chicago, Ill. (E. H. Christopherson, 1801 Hinman Ave., Evanston, Ill.)

20–23. American Psychiatric Assoc., Kansas City, Mo. (1700 18 St., NW, Washington 6.)

21. American Soc. of Safety Engineers, annual, Chicago, Ill. (J. B. Johnson, 425 N. Michigan Ave., Chicago 11.)

22–24. American Assoc. of Petroleum Geologists, southwestern regional, Mineral Wells, Tex. (R. H. Dott, Box 979, Tulsa 1, Okla.)

22–24. Aviation Medicine, 4th annual symp., Santa Monica, Calif. (T. H. Sternberg, UCLA Medical Center, Los Angeles 24, Calif.)

22–26. American Soc. for the Study of Arteriosclerosis, annual, San Francisco, Calif. (O. J. Pollak, P.O. Box 228, Dover, Del.)

23–25. National Soc. of Professional Engineers, San Francisco, Calif. (K. E. Trombley, NSPE, 2029 K St., NE, Washington 6.)

23–25. Rocket Technology and Astronautics, intern., Essen, Germany. (Deutsche Gesellschaft fuer Raketentechnik und Raunfahrt, e.v., Neunsteinerstrasse 19, Stuttgart, Zuffenhausen.)

24–25. International Conference on the Insulin Treatment in Psychiatry, New York, N. Y. (M. Rinkel, 479 Commonwealth Ave., Boston 15, Mass.)

24–25. Taxonomic Consequences of Man's Activities, symp., Mexico, D. F. (H. C. Cutler, Missouri Botanical Garden, St. Louis.)

24–28. American Heart Assoc., San Francisco, Calif. (J. D. Brundage, 44 E. 23 St., New York 10.)

27–28. Child Research in Psychopharmacology, conf., Washington, D.C. (S. Fisher, Psychopharmacology Service Center, Natl. Inst. of Mental Health, Bethesda 14, Md.)

27–28. Plant Physiology, 9th annual research cong., Saskatoon, Saskatchewan, Canada. (D. T. Coupland, Plant Ecology College of Agriculture, Univ. of Saskatchewan, Saskatoon.)

27–29. Radio, Institute of Radio Engineers, fall meeting, Rochester, N.Y. (V. M. Graham, EIA, 11 W. 42 St., N.Y.)

(See issue of 15 August for comprehensive list)

Letters

Machines and the Brain

In the last few years there has been an epidemic of published statements, articles, and books which take for their subject the relationships of machines to brains. Many of these theses have been loosely constructed and have been filled with gross oversimplifications, vague approximations, and unjustified assumptions. Certainly some comparisons and contrasts can be made between known machines and human brains, but the paucity of knowledge of the latter mechanism has given rise to numerous ill-advised speculations. My general concern here is to attempt to attack some of this foggy thinking and, in particular, to respond to the article "Machines and the brain" by F. H. George, published in the 30 May 1958 issue of Science [**127**, 1269 (1958)].

It is asserted in that article that cybernetics has seriously proposed that the brain is a complex two-valued switching device. A more accurate observation is that the switchboard theory of nervous conduction was disappearing at just about the time that cybernetics first came on the scene. Wiener (*1*) himself suggested the possibility of a complex nondigital neural mechanism in addition to the well-known all-or-none transmission. Since then there has been ample evidence for synaptic and humoral

mechanisms which form continuously variable, long time-constant systems. These systems, at least as complex as those using two-valued axonal transmission, mediate the performance of the binary systems. If one must speculate about the nature of the cerebral processes it may be reasonable to say that the flow of information between parts of the brain is essentially "digital" while the logical operations themselves are "analog." The futility of even hoping for adequate mathematical descriptions of the brain is made painfully clear when von Neumann observes (2) that the nervous system operation must differ considerably from what we consciously and explicitly consider to be mathematics.

George has equated simulated nerve nets to biological nervous tissue, implying that the flow of binary signals through explicit logical networks can form a reasonable basis for understanding brain function. One of the most embarrassing pieces of clinical evidence which such notions must explain is that very considerable portions of human brain can be removed without apparently destroying memory or function. In the ablation of a complete cortical hemisphere some five billions of the elements can be removed without much observable effect.

George has the discomfiting habit of implying much while actually saying little and therefore leaving the reader with more flavor than sustenance. The section entitled "Development of nets" illustrates this when the time comes to develop the nets and one finds that the author "leaves the matter for the time," never to return. He agrees throughout this section that certain things should be said, then neatly side-steps with comments that these matters have been discussed elsewhere; unfortunately, references to the "elsewheres" are not given.

George's "summary" of our knowledge of the human visual system is of dubious value. Even a cursory summary of that vast body of information (3), written for an interdisciplinary audience, could easily occupy a small volume. The "summary" which is given is a curious mixture of gross anatomy, psychophysics, and speculation. There is a section of this summary which is truly incredible. It is:

> Perhaps the most interesting feature of the visual pathways is the effect of summation resulting from the fact that information is being passed through a restriction. (Something very similar is seen in the auditory pathways.)
>
> The passing of information through a restriction is something that is characteristic of the central nervous system and makes temporal summation a necessity. It should be mentioned straightway that there is no difficulty in showing how this can be done in logical network terms.

To this I can only observe that the words and sentences are quite clear; it is only the meaning which is baffling.

One of the great puzzles to neurophysiologists, neuroanatomists, and psychologists alike concerns the origin and function of the alpha rhythm. There is not even a good set of speculations extant for explaining this brain-wave phenomenon, yet George confidently describes it as a scanning system to offset blurring due to aftereffects of retinal stimulation.

The impression is given that, after all, the cerebral cortex is a simple structure, only it contains so many variables that its description must be made in probabilistic terms. The author asserts that intercortical and subcortical connections "can be approximated by quite simple mathematical functions." This is extremely misleading in view of the fact that a *single* neuron may have hundreds of dendritic connections and as many, or more, synaptic processes. Even if we completely understood this "simple" unit and its time-varying parametric rules (which must include charge distribution, ionic concentration, membrane and hu-

moral conditions), an adequate description for it would very likely be far from simple. To further construct a mathematical model for a modest volume of these elements (a single cubic centimeter contains roughly ten million of them) is an even more complicated task. We must then include statements about temporal and spatial summation, relative and absolute refractoriness, inhibition, and delay.

Most of those who have done "nervenet" modelling have been careful to state that their constructs are extremely gross oversimplifications. In his "Probabilistic Logics" (*4*), von Neumann cautions that identifying the real physical or biological world with models constructed to explain it is indeed dangerous and that even plausible explanations should be taken with a very large grain of salt.

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References and Notes

1. N. Wiener, *Cybernetics* (Wiley, New York, 1948), p. 142.
2. J. von Neumann, *The Computer and the Brain* (Yale Univ. Press, New Haven, Conn., 1958), pp. 80–82.
3. See, for example, S. L. Polyak's 600-page volume *The Retina* or the same author's *The Vertebrate Visual System*, containing 1390 pages, 300 of which are devoted to bibliography.
4. J. von Neumann, "Probabilistic Logics," included in *Automata Studies* (Princeton Univ. Press, Princeton, N.J., 1956).

I have been kindly allowed to reply to the criticisms made by L. D. Harmon about my article "Machines and the brain," published in *Science*, 30 May 1958.

It is perhaps most appropriate to start with some admissions. Insofar as I may have created the impression that the cerebral cortex is simple, that machines could easily be built to simulate it in detail, or that everything is now cut-and-dried in digital terms, then I have certainly been guilty of misleading my readers. It may be easy enough in this sort of subject to create a false impression, and many writers have certainly made exaggerated claims.

That my writing and thinking may sometimes be foggy, as Harmon suggests, is a fact of which I am all too well aware. More particularly, I agree with the late John von Neumann's warning about *identifying* models with physical or biological systems. Von Neumann had a large influence on my own thinking—especially during a year spent at Princeton (1953–54)—and I would certainly never encourage identification of model and system modelled; nor, indeed, did I ever suggest such a foolish procedure.

I will now turn briefly to the task of justifying myself.

I would certainly claim that the meth-

ods of *finite automata* are of the greatest use in building models of the human brain. This is not to imply that the human brain can be wholly modelled as a digital system (Turing guessed that it was part digital and part analog, and with this most of us would agree). If, however, we were able to mirror many aspects of the brain in such digital terms, it would then be relatively easy to replace digital by analog parts. The procedure is essentially an *effective* one. It also has (and for this reason of its *effectiveness*) a clarifying effect on the concepts we use in neurophysiology.

The example Harmon quotes of brain destruction is an interesting one. This work is associated, primarily, with the name of Lashley. He certainly found that an alarming number of cortical areas could be destroyed, at least in rats, and there is much evidence from frontal lobotomy and other operations in human beings that show the same sort of thing. But why, one wonders, does Harmon imply that this is a special difficulty? The work of D. O. Hebb has already suggested a method for dealing with these results, and von Neumann's principle of multiplexing could certainly be used to account for them. Clearly, any model that claims to be sufficient for brain-model purposes will not depend on precise element-by-element efficiency. Since a large number of elements must be kept in reserve for the mediation of "new ideas," destruction of elements may well have the effect of destroying "creative" capacity.

Unfortunately, limitations of space forbid that I should treat the remainder of Harmon's remarks in detail. But I will summarize further comments in the form of a brief list. (i) Restriction and temporal summation are characteristics of central nervous tissue (see J. T. Culbertson); Harmon's example of my prose is not so convincing, although I would now write it rather differently. (ii) The switchboard theory of the nervous system is by no means out of fashion, and research is increasingly being done on it, perhaps especially in Britain. (iii) I believe it is possible that the cerebral cortex is indeed constructed on relatively simple principles, although, like the digital computer, it gains its great complexity from the enormous number of its elements. (iv) Although, unfortunately, no work has yet been published on the logical interpretation of the alpha rhythm, a great deal of work has been done in this field in Britain (*1*) and will soon, it is hoped, be published.

There is a great deal more to be said on this vast topic of brain models, and I would take this opportunity to emphasize the enormity of the problem of modelling the brain. I believe that the functional aspects are indeed more easily approachable than the anatomical. Nevertheless, there seems to be some reason for optimism about the future of the very powerful methods of cybernetics.

I would also like to take the opportunity to give a few of the many references (*2*) for the work referred to here and previously. I do not repeat the references (all of great importance) in Harmon's note.

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References

1. D. J. Stewart, "A notation for logical networks" and other unpublished notes.
2. J. T. Culbertson, *Consciousness and Behavior* (Brown, Dubuque, Iowa, 1950); F. H. George, "Logical networks and behavior," *Bull. Math. Biophys.* 18, 337 (1956); ———, "Logical networks and probability," *Bull. Math. Biophys.* 19, 187 (1957); D. O. Hebb, *The Organization of Behavior* (Wiley, New York, 1949); S. C. Kleene, "Representation of Events in Nerve Nets and Finite Automata," *Rand Research Mem. No. RM704*; W. S. McCulloch and W. Pitts, "A logical calculus of the ideas imminent in nervous activity," *Bull. Math. Biophys.* 5, 115 (1943); A. M. Turing, "On computable numbers," *Proc. London Math. Soc.* (*1936–37*), ser. 2, vol. 42, pp. 230–65; A. M. Uttley, "The classification of signals in the nervous system," *Electroencephalog. and Clin. Neurophysiol.* 6, 479 (1954); ———, "The Conditional Probability of Signals in the Nervous System," *Rand Research Mem. No. 1109.*

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